DOCUMENT RESUME

ED 231 427 JC 830 237

AUTHOR	Bolin, William Everet; Orsak, Charles G., Jr.
TITLE	Solar Energy: Materials, Materials Handling, and Fabrication Processes: Student Material. First Edition.
INSTITUTION	Navarro Coll., Corsicana, Tex.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	82
NOTE	447p.; For related documents, see JC 830 235-240. Materials developed in consortium with North Lake College, Brevard Community College, Cerro Coso Community College, and Malaspina College.
PUB TYPE	Guides - Non-Classroom Use (055)
EDRS PRICE	MF01/PC18 Plus Postage.
DESCRIPTORS	Carpentry; Class Activities; Community Colleges; *Construction (Process); Electrical Systems; *Energy Occupations; Equipment; Glass; Measurement; Measurement Equipment; Plumbing; Power Technology; Safety; Safety Education; Sheet Metal Work; *Solar Energy; Technical Education; Two Year Colleges; Welding
IDENTIFIERS	Insulation; Soldering

ABSTRACT

Designed for student use in "Materials, Materials Handling, and Fabrication Processes," one of 11 courses in a 2-year associate degree program in solar technology, this manual provides readings, exercises, worksheets, bibliographies, and illustrations for 13 course modules. The manual, which corresponds to an instructor guide for the same course, covers the following topics: (1) general shop safety; (2) units of measuring and measuring devices; (3) hand tools/power tools and fasteners; (4) welding; (5) carpentry; (6) sheet metal; (7) roofing, flashing, and pitch pans; (8) soldering; (9) piping practices; (10) glazing materials; (11) material coatings and materials compatability; (12) insulation; and (13) electrical practices. (AYC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED231427

SOLAR ENERGY

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

Student Material

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

C. G. Orsak

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

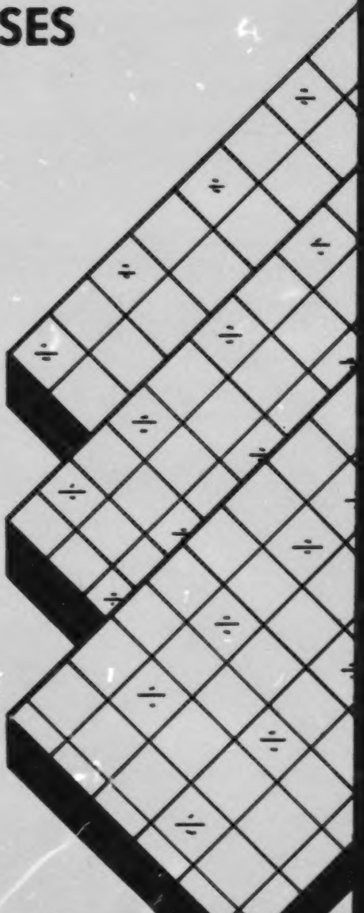
U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☒ Minor changes have been made to improve reproduction quality.

● Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

JC 830 237



NAVARRO COLLEGE
CORSICANA, TEXAS

Student Material

MATERIALS,

MATERIALS HANDLING,

AND FABRICATION PROCESSES

PRIME AUTHOR
William Everet Bolin

PROJECT DIRECTOR
Charles G. Orsak, Jr.
Navarro College

TECHNICAL COORDINATORS

William Everet Bolin
North Lake College

Stephen Pomroy
Navarro College

Ray Mudrak
Brevard Community College

Jeff Jacobs
Cerro Coso Community College

Dr. Jim Slater
Malaspina College

FIRST EDITION

1982

*Neither the United States Government, National Science Foundation,
nor Navarro College, its contractors or employees
makes any warranty, expressed or implied,
or assumes any legal obligation, liability or responsibility
for the* ***accuracy****, completeness, or usefulness
of the information presented,
or represents that its use would not
infringe privately owned rights.*

*Brand names, company names, trademarks,
or other identifying symbols appearing in the text are
used to clarify and identify and do not constitute a
recommendation or endorsement.*

Materials developed by
Navarro College
in consortium with
North Lake College,
Brevard Community College,
Cerro Coso Community College,
Malaspina College
in cooperation with
The National Science Foundation
Project No. SED 80-19327.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES
Student Material

CONTENTS

Preface. v

Acknowledgments. vii

Use of Student Materials .ix

General Shop Safety. IV-S-1

Units of Measuring and Measuring Devices IV-S-21

Hand Tools/Power Tools and Fasteners IV-S-35

Welding. IV-S-63

Carpentry. IV-S-95

Sheet Metal. IV-S-141

Roofing, Flashing and Pitch Pans IV-S-173

Soldering. IV-S-219

Piping Practices IV-S-237

Glazing Materials. IV-S-269

Material Coatings, Materials Compatability IV-S-329

Insulation IV-S-359

Electrical Practices IV-S-411

PREFACE

The United States is facing one of its most challenging decades in recent history. Fuel supply and inflationary prices have forced us to consider alternate energy sources as a means of preserving our standard of living, industrial society, and economic stability. One such alternative is solar.

Presently, foreign crude oil provides the raw material for about one-half the liquid fuel production in the U.S. Political instability in foreign oil-producing countries underscores the need to decrease our ever-growing dependency on foreign energy sources and to lessen our vulnerability to such imports. Solar energy as an alternate can be used as a renewable domestic energy source and to supplement our increasing appetite for oil.

To help bring about the potential for solar energy, there must be a cadre of trained technicians to design, install, troubleshoot, and market solar energy so that the consumer can feel comfortable in the market's ability to service and react to his/her solar energy needs.

With the support of the National Science Foundation, Navarro College, in consortium with North Lake College, Brevard Community College, Cerro Coso Community College, and Malaspina College, has developed and pilot tested a two-year associate degree curriculum to train solar technicians. It can be duplicated or replicated by other educational institutions for their training needs.

The two-year technician program prepares a person to:

1) apply knowledge to science and mathematics extensively and render direct technical assistance to scientists and engineers engaged in solar energy research and experimentation;

2) design, plan, supervise, and assist in installation of both simple and complex solar systems and solar control devices;

3) supervise, or execute, the operation, maintenance and repair of simple and complex solar systems and solar control systems;

4) design, plan, and estimate costs as a field representative or salesperson for a manufacturer or distributor of solar equipment;

5) prepare or interpret drawings and sketches and write specifications or procedures for work related to solar systems; and

6) work with and communicate with both the public and other employees regarding the entire field of solar energy.

This curriculum consists of nine volumes:

1) an Instructor's Guide for the eleven solar courses, to include references, educational objectives, transparency masters, pre-tests and post-tests, and representative student labs;

2) an Implementation Guide addressing equipment, commitment, and elements to be considered before setting up a solar program;

3) Student Material for each of seven of the core solar courses:
   - a) Materials, Materials Handling, and Fabrication Processes;
   - b) Sizing, Design, and Retrofit;
   - c) Collectors and Energy Storage;
   - d) Non-Residential Applications;
   - e) Energy Conservation and Passive Design;
   - f) Codes, Legalities, Consumerism, and Economics;
   - g) Operational Diagnosis.

ACKNOWLEDGMENTS

Throughout this project, many people and institutions have contributed greatly to the development, pilot test, and completion of the solar technology curriculum. First, this project owes a debt of gratitude to the National Science Foundation whose support and encouragement have made this project possible. Specifically, two individuals formerly with the National Science Foundation deserve recognition: Dr. Bill Aldridge and Dr. Gregg Edwards.

Appreciation is extended to thos members who served on the Advisory Committee and provided valuable input to module content, text format, and the pilot test plan and evaluation:

Tom Hindes, (Chair for Phase II and III), Ohio State University.
Dr. Phil DiLavore, (Chair for Phase I), Indiana State University.
Dr. David Gavenda, University of Texas at Austin.
Dr. Milton E. Larson, Colorado State University.
Dr. Jeff Morehouse, Science Applications, Inc.
Glenn Meredeith, President, Ham-Mer Consulting Engineers, Inc.
Pearley Cunningham, Community College of Allegheny County.
Dr. Max Jobe, (Eveluator), East Texas State University.

It would have been impossible to complete this project and all the curriculum materials if it had not been for the Technical Coordinators and the Cooperating Institutions in this Consortium:

William Everet Bolin, North Lake College, Dallas, Texas.
Ray Mudrak, Brevard Community College, Titusville, Florida.
Stephen Pomroy, Navarro College, Corsicana, Texas.
Jeff Jacobs, Cerro Coso Community College, Ridgecrest, California.
Dr. Jim Slater, Malaspina College, Nanaimo, British Columbia.

A special thanks is sent to Dr. Pete Signell and his staff, Tom Burt and Jodee Fortino, and the resources at Michigan State University for their help in providing computer assistance to produce the printed masters for the project and permanently store the curriculum in their data bank.

There are others who have contributed to the content, technical authority, and clerical tasks of the project who have made this a learning experience for us all:

Charles Younger
Jim Knowles
Bunnie Thompson
Shirley Farrow
Julius Sigler
Wayne Silva
Kevin O'Conner
Alan Boyd
Pete Fry
Bob Takacs
Mike Lowenstein (Director Phase I)
Art Meyers (Director Phase II)
Kay Garrett
Pam Scarrow
Elna Baird
Sandra Foster
Estelle
Cynthia Bolin
Jeremy Pereira
Carol Mitchell

My personal thanks go to Bill Bolin for all his help, and to my wife and children for their emotional support.

USE OF THE STUDENT MATERIALS

The intent of this manual is for student use as a supplement to the instructor's guide for the same course. It contains readings, exercises, worksheets, bibliographies, and illustratons to reinforce the concepts contained within this particular course of study. Each student materials manual is written in a similar format but differs in some details due to the nature of the course and the subject matter covered.

Pretests, posttests, and lab exercise are not contained in this manual. Refer to the instructor's guide for this course to find these items.

Student materials manuals are supplied for seven of the eleven solar courses in this project. The four not included are: Introduction to Solar Energy, Energy Science I, Energy Science II, and the Practicum.

The pagination code is used as follows:

I -- the Roman numeral coordinates with the Ronan numeral of the instructor's guide.

S -- the "S" signifies that the page is from the Student Material.

5 -- the Arabic number reflects the specific page within this manual, numbered sequentially throughout.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

GENERAL SHOP SAFETY

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

GENERAL SHOP SAFETY

The primary goal of any worker should be:

1. Do the assigned or required task to the best of your ability.
2. Work as safely as possible with accident prevention in mind at all times. Always ask the question: "Is there a safer way to do the job?"
3. 88% of accidents are caused by unsafe acts of people, 10% by physical hazard and only 2% by uncontrollable phenomena.

Work area may contain many potential safety hazards unless specific rules are followed. Following are some of the warning signs for potential hazards.

1. Poor housekeeping.
   A work area that is kept clean and orderly can prevent many accidents such as bruises, broken bones, cuts, gauges, burns, others too numerous to list here.

   Items for consideration in good housekeeping practices are as follows:

   A. Keep all floors and walkways clean and dry. If liquids, such as oil, water or grease is spilled, clean it up immediately using absorbent if required.

   B. Keep all working areas well lighted. You can not work safely in dim or poorly lighted areas.

   C. Insure that the area is well ventilated at all times. Vapors from many highly volatile and toxic chemicals can be injurious to your health.

   D. Don't leave tools scattered about the floor or work space. Scattered tools, specifically on scaffolds, may fall and injure someone below.

   E. Don't lift objects that are too heavy. Get some help. If your toolbox is very heavy, divide the tools in two boxes.

   F. Keep seldom used items in a safe storage place.

   G. Keep all ropes, chains, cables, hoses and power cords properly stored when not in immediate use.

   H. Store oily or greasy rags in a fireproof metal container.

   I. Store scraps tubing, wire, sheet metal, glass, etc. in containers making sure they do not extend beyond the edge of the container. These cause nasty cuts, bruises and punctures.

J. Provide periodic (monthly) inspection of all power cords, cables, switch gear or other devices that might be hazardous if excessive wear went undetected.

K. Inspect the shop area weekly, no less than bi-weekly, for unsafe conditions that may have gone unnoticed.

L. Make a safety check list for all shop equipment, i.e., drill presses, grinders, punch presses, power tools, metal shears and brakes, etc., and require a signature of the party responsible for such inspection.

M. Keep lunch areas, water fountains, food dispensers and clothing lockers in sanitary condition. Illnesses from these areas can be more devastating than accidents.

Horseplay, although done in fun, can be one of the most dangerous activities in a working area. "Friendly" shocks, hot foots or goosing can cause the recipient to be severely injured from the reaction to the intended "fun". He might fall into high voltage or moving machinery. If lucky, he might "only break an arm". There is no way that horseplay can be justified.

Equipment with moving parts, such as, belts, chains, flywheels and moving arms can be very dangerous unless proper care is exercised during operation and maintenance.

Protective covers of moving parts (flywheel covers, belt guards, etc.) should not be removed when machinery is operational. If repairs requiring removal of guards are required, stop the machinery.

A. Clothing - should fit snugly, long sleeves should be buttoned (loose sleeves are dangerous). Gloves, neckties, wristwatches and rings are very hazardous.

B. Lifting of heavy objects using improper techniques can result in permanent damage to ones back. Lift with the legs and knees, not the back. Make sure the footing is secure before attempting the lift and then lift with the back straight. Carry each load close to the body without shifting the grip and be certain that you have an unobstructed view of the floor ahead. Keep a watchful eye for slippery materials on the floor.

   Any object too heavy for one person should be handled by two people. If two people can not safely carry the object, use a mechanical device.

All of the previously stated safety rules also apply to the specific area of Electrical Safety.

Almost everyone is required to work on or around electrical circuits as they do their job in the Air Force. You cannot see electricity; therefore, you cannot determine by looking at a conductor if it is energized by voltage. Also, you cannot determine the amount of voltage applied to the conductor. In order to work safely around electrical, you must understand the following:

* Operation principles of AC and DC electricity.

* Functions of the electrical circuits you maintain.

* Use of electrical safety equipment.

* Safety precautions to be observed.

* Conditions which cause an electrical shock.

* Effects of an electric shock.

A number of people are electrocuted each year because they fail to understand one or more of the above items. For example, when a person is electrocuted, death resulted from which of the following:

* Voltage

* Current

* Resistance

An electrical shock includes all three of these factors. However, "current" is the "killer" in the case of electrical shock.

Voltage is an electrical pressure which causes tiny electrically charged particles (electrons) to flow through a conductive material.

Current is the movement of these tiny electrically charged particles (electrons) through the conductive material. Movement of electrons through the human body affects the muscles and nervous system. When the current exceeds a certain value, the muscles affected become paralyzed. This causes the heart to stop beating and the lungs to stop functioning. If this condition prevails long enough, death results.

Resistance is the factor which opposes the flow of current. The amount of resistance that the human body has depends on certain conditions. The skin, when dry, has a high resistance. This skin characteristic acts to protect a person from electrical shock by low voltages. However, when the skin is wet or damp, it has a smaller amount of resistance. Therefore, a person whose skin is wet may be electrocuted by low voltage (about 100 volts), while a person with dry skin may not be electrocuted with voltages of this low value.

Effects of Electric Shock

Electric shock may cause instant death or unconsciousness, cessation of breathing, and burns of all degrees. If a 60-cycle alternating current is passed through a person from hand to hand, or from hand to foot, the effects when current is gradually increased from zero are as follows:

* At about 1 milliampere (0.001 ampere) a slight shock can be felt.

* At about 10 milliampere (0.010 ampere) the shock is severe enough to paralyze muscles so that a person may be unable to release the conductor.

* At about 100 milliampere (0.100 ampere) the shock is fatal if it lasts for one second or more.

Almost all electrical injuries are caused by carelessness or overconfidence in handling equipment. Most personnel are likely to think in terms of high voltages, but death lies in the low voltages too. The following facts are presented to illustrate the hazards of low voltage.

The human skin, through its resistance, acts as a protector against electrical shock. This resistance to electrical current varies between 100,000 and 600,000 ohms for dry skin. It may be as low as 1000 ohms for wet skin. The resistance of the internal body, hand to foot, is about 400 to 600 ohms, and from ear to ear, 100 ohms.

Assume that 120 volts is applied to the perspiring skin of a worker who is standing on a good electrical ground. Further assuming the worker has a total resistance of 1500 ohms, the current through him would be about 0.08 ampere or 80 milliamperes. This amount of current is not always fatal, but is is painful. It causes severe muscular contractions and makes breathing difficult. If the current absorbed is between 100 and 200 milliamperes, it produces a heart condition, wherein the heart muscle fibers work independently and without rhythm, causing instant death.

Electrical Maintenance

Here is the possibility of injury to personnel, the danger of fire, and possible damage to materials. Therefore, all repair and maintenance work on electrical equipment should be performed only by duly authorized and assigned persons.

When any electrical equipment is to be overhauled or repaired, the main supply switches should be shut off. This includes switches in each circuit from which power could possibly be fed. The covers of fuse boxes and junction boxes should be kept securely closed except when work is being done. Safety devices such as interlocks, overload relays, and fuses should never be disconnected except for replacements. Safety or protective devices should never be changed or modified in any way without specific authorization. Fuses should be removed and replaced only after the circuit has been deenergized. When a fuse blows, it should be replaced only with a fuse of the same current and voltage ratings. When possible, the circuit should be carefully checked before making the replacement, since the burned-out fuse is often the result of a circuit fault.

If practicable, repair work on energized circuits should NOT be undertaken. When repairs on operating equipment must be made in order to make proper adjustments, every known safety precaution should be carefully observed. Proper lighting should be provided, and the worker should be insulated from ground with some suitable non-conducting material. A helper should be stationed near the main switch or the circuit breaker so that the equipment can be deenergized immediately in case of emergency. A person qualified in first aid for electric shock should stand by during the entire period of the repair. During this type work on energized circuits, safety equipment in the form of gloves, blankets, covers, safety tools, etc., must be used.

Personnel should never work alone near high voltage equipment. Even very high body resistance and resistance offered by protective clothing and equipment can be offset by high voltages. Tools and equipment containing metal parts should not be used near the high voltage circuits or equipment. Handles of all metal tools, such as pliers should be covered with rubber insulation. Warning signs and suitable guards should be provided to prevent personnel from coming into accidental contact with high voltages.

Work on electrical equipment should not be accomplished with wet hands or while wearing wet clothing, since this would greatly reduce body resistance. Wearing thin-soled shoes with metal plates or hobnails is unwise. Safety shoes with nonconducting soles should be worn if available. Flammable articles, such as celluloid cap visors, or electrical apparatus, all rings, wristwatches, bracelets, and similar metal items should be removed. Care should be taken that the clothing does not contain exposed zippers, metal buttons, or any type of metal fasteners.

Most portable tools are equipped with a ground wire and a standard ground plug. This will protect the operator in the event of a short circuit within the equipment. The gound wire must be connected to an approved ground and should have a total resistance of less than one ohm. Extreme care must be exercised to see that the ground connection is made correctly. If the equipment casing grounding conductor is connected by mistake to a line contact of the plug, a dangerous potential will be placed on the equipment casing. This might easily result in a fatal shock to the operator.

Before touching a capacitor which is connected to a deenergized circuit, you should short-circuit the terminals to make sure that the capacitor is completely discharged. Grounded shorting prods should be permanently attached to workbenches where electrical or electronic devices are regularly serviced.

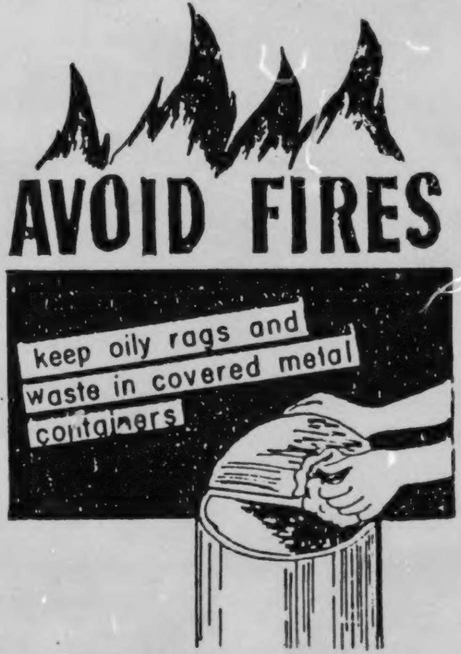
In addition to electrical hazards involved when working with batteries, the danger of acid burns is also present. These burns can be prevented by the proper use of full faceshields, or protective chemical goggles, rubber gloves, rubber aprons, and acid-resistant safety shoes, or rubber knee length (safety-cap) boots. Another battery hazard is the danger of explosion due to the ignition of hydrogen gas given off during the battery charging operation. This is especially true where an accelerated charging method is used. Open flames or smoking should not be permitted in the battery charging room, and the charging rate should be held at a point that will prevent rapid liberation of hydrogen gas. Manufacturer's recommendations as to the charging rates for various size batteries should be closely followed; also, an adequate shop exhaust system should be used.

Fire Prevention

While firefighting is the prime responsibility of the area fire department, it is the duty of each individual to do his utmost in preventing fires, and to aid in extinguishing them. This topic will cover the various types of fires and the measures to apply in controlling them.

Good housekeeping is essential in the effective prevention of fires. Accumulations of rubbish, waste, dust, and other residue are all sources of fires. One of the most important measures in fire prevention is shown below.

Another serious fire hazard is the accumulation of fuel vapors, gases, paint vapors, and other items of this nature. To eliminate this type of hazard, keep your shop clean and well ventilated. Proper inspection and maintenance of equipment will usually correct hazards due to leakage of flammable materials. Generally, all painting should be accomplished in an approved paint shop. When this is not possible, the need for adequate shop ventilation becomes critical. Paint will burn, so will its vapors; therefore, use extreme care when painting with a spray gun. Prevent fires whenever you can, but also know something about firefighting in the event you can't prevent them all.


AVOID FIRES
keep oily rags and waste in covered metal containers

Fire Prevention at Work

Classes of Fires

Fires are grouped into four general classes. Fires in each class can be extinguished by the use of a particular action or extinguishing agent. Because all fire extinguishing agents cannot be used on all types of fires, it is necessary to know the various classes of fires and which extinguisher to use for each class.

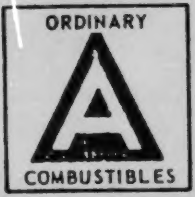
Class A fires are fires occuring in wood, clothing, paper, rags, and other items of this nature. This type of fire can usually be handled effectively with water. Water provides the cooling and quenching effect necessary to extinguish Class A fires.

Class B fires are those occurring in flammable liquids such as gasoline, fuel oil, lube oil, grease, some solvents, paints, etc. The agents required for extinguishing this type of fire are those which will dilute or eliminate the air by blanketing the surface of the fire. This action creates a smothering effect.

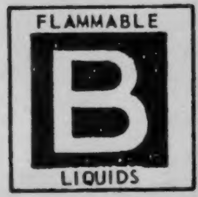
Class C fires are fires in electrical equipment and facilities. The extinguishing agent for this type of fire must be a nonconductor of electricity and provide a smothering effect.

Class D fires occur in combustible metals such as magnesium, potassium, powdered aluminum, zinc, sodium, titanium, zirconium, and lithium. The extinguishing agent for this type fire must be a dry-powdered compound. The powdered compound must create a smothering effect.

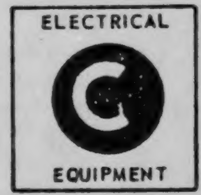
Recommended Guide for Marking Fire Extinguishers. This guide has been extracted from the National Fire Code, volume 8, standard 10, appendix B.



Extinguishers suitable for Class A fires should be identified by a triangle containing the letter "A". If colored, the traingle will be green.

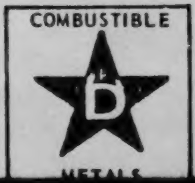


Extinguishers suitable for Class B fires should be identified by a square containing the letter "B". If colored, the square will be red.



Extinguishers suitable for Class C fires should be identified by a circle containing the letter "C". If colored, the circle will be blue.

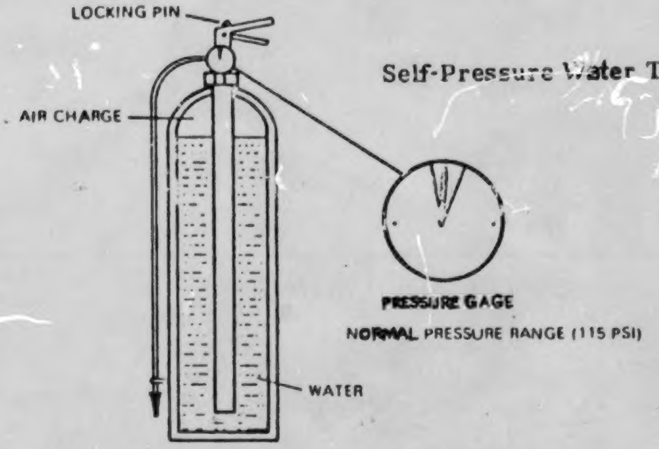
Extinguishers suitable for Class D fires should be identified ay a five-pointed star containing the letter "D". If colored, the star will be yellow.



In the case of any fire, there are certain steps required of the individual who discovers the fire. The first step is to sound the alarm to alert all personnel. Second, call the fire department and give the location of the fire. These first two steps must be taken quickly, and after they have been accomplished, the personnel available should apply the most effective measures available to extinguish or to contain the fire. To do this, it is essential that you acquire a knowledge of the various types of portable fire extinguishers.

Portable Fire Extinguishers

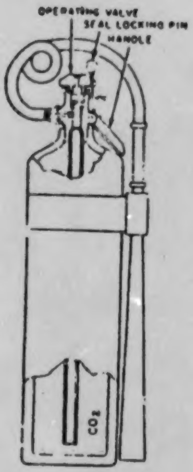
The self-pressure water type portable extinguisher is the most widely used of the portable extinguishers. Self-pressure means that the container is pressurized; one type contains an air charge which forces the water out of the container when the handle is squeezed. Refer to the figure below. To determine if the air charge is within limits, look at the gage located near the handle. The pressure, as indicated on the gage, should be in the normal range. Remember, water is the extinguishing agent, so use only on Class A fires. To operate, remove locking pin, direct hose toward base of fire, and squeeze the handle.



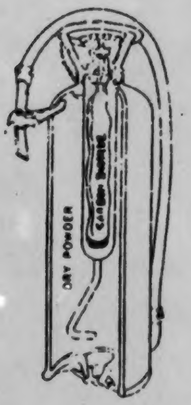
Self-Pressure Water Type Extinguisher

Carbon Dioxide or CO_2 type extinguishers may be used on Class B and on Class C fires. This unit is shown on next page. To operate the CO_2 extinguisher, pull the seal locking pin and open the operating valve. The CO_2 should be directed toward the base of the fire with a sweeping motion.

Dry Chemical type extinguishers may also be used on Class B and C fires. These units contain a dry powder, usually sodium bicarbonate, and an activating agent of CO_2 or nitrogen gas. Refer to figure on next page for an illustration of the dry chemical extinguisher. These units should not be used on trash fires. To put the extinguisher into use, remove the locking pin, open the cartridge discharge valve and squeeze the nozzle handle.



CARBON DIOXIDE



DRY CHEMICAL

There are other types of portable fire extinguishers in use at various installations. For information about these many different devices, refer to AFR 127-101.

Remember, a stitch in time saves nine. If you can extinguish a fire while it is still small you can, in some cases, prevent a major disaster. The only way you can effectively fight fires is to be able to readily classify the fire and know which extinguisher to use in each case. Also, you must know how to use each extinguisher.

Electrical Fires

General cleanliness of the work area and of electronic apparatus is essential for the prevention of electrical fires. Oil, grease, and carbon dust can be ignited by electrical arcing. Therefore, electrical and electronic equipment should be kept absolutely clean and free of all such deposits.

For combating electrical fires, a CO^2 (carbon dioxide) type fire extinguisher is recommended. Water type extinguishers should not be used since the water will conduct electricity. In cases of cable fires in which the inner layers of insulation or insulation covered by armor are burning, the only positive method of preventing the fire from running the length of the cable is to cut (with insulated equipment) the cable and separate the two ends. When cutting cables it is vital to insure that all electrical power has been disconnected.

Hand and Power Tools

The improper use of common hand and power tools results in many avoidable accidents. One of the prime rules in the use of any tool is to use the right tool for the right job. Another prime rule is to keep all tools in a good state of repair. Also keep tools in their proper space so that they can be used when needed. Some important safety items to consider in the use of tools are given in the paragraphs below.

- When possible, use handtools so that the working force is always directed away from your body. This will minimize the chances of injury in case the tool should slip. One exception to this rule is the use of wrenches.

- When handles of hammers, sledges, files, and other tools become splintered or loose, replace them immediately.

- Mushroom heads on cold chisels, punches, driftpins, hammers, and other similar tools should be dressed down as soon as they begin to check and curl.

- Cutting tools should be kept sharp and kept in their proper sheaths. They should never be placed in clothing pockets.

- Box end type wrenches or sockets should be used whenever possible. They are less likely to slip than open end and other type wrenches. Another thing, if a job requires a special tool, use a special tool. To help prevent slippage, a wrench handle should be pulled, never pushed.

- Impact goggles or faceshields must be worn any time there is danger of flying chips, sparks, or other debris.

- Small parts should always be held securely in a vise while being worked on.

- Since hammers account for about one in every five handtool accidents, care must be observed in their use. Hammer handles should never be used as pry bars, punches, or chisels. Never use a file or rasp without the proper handle installed, you may drive the tang right through your hand.

- Punches and chisels should be kept clean and during use, should be held firmly between the thumb and all four fingers.

There are many more safety precautions to observe in the use of handtools; however, the space here prohibits listing them.

The use of powered handtools requires generally the same precautions as for non-powered tools, plus additional safety precautions. In the case of electrical tools, cleanliness and a good state of repair is of the utmost importance. In addition to keeping the tools and electrical cords in first-rate condition, the tool should always be properly grounded during use. This protects the worker against the danger of electrical shock in the event a short circuit occurs within the tool. This need for grounding is often disregarded, but it is important and must never be omitted. Another important precaution is to always secure the item being worked on in a vise. Never hold a piece of material by hand and attempt to drill it with an electric drill. The material may catch on the drill bit and become a rapidly spinning blade.

Most power tools are accompanied by safety tips for safe use of these tools. Read them carefully and watch out for "shortcuts". They can frequently result in exactly that, shortened fingers, arms or other limbs or eyes.

Observe Accident Prevention Signs.

WARNING SIGNS. Warning signs are posted for one reason only. That reason is to prevent accidents. There may be times when you see an area posted which you do not consider a hazardous area. In these cases just remember that someone had a good reason to post the area, so observe the warning sign.

Standard signs are posted to warn of certain hazards: Danger signs (red) warn of specific dangers only; Caution signs (yellow) warn of possible dangers and unsafe practices; Safety Instruction signs (green) provide information on general safe practices; Directional signs (black and white) indicate the way to stairways, fire escapes, exits, etc.; Information signs (also black and white) carry messages of a general nature.

Here are some of the signs you will see: DANGER HIGH VOLTAGE, DANGER KEEP OFF, DANGER KEEP AWAY, DANGER NO SMOKING, DANGER GASOLINE, CAUTION DO NOT TOUCH SWITCHES, CAUTION MEN WORKING, CAUTION USE GUARD, and many more.

There are many items of protective clothing and equipment developed for your protection. The complexity of this equipment ranges from simple items such as gloves, goggles, hardhats, etc., to more complicated items including respirators, self-contained breathing apparatus, and complete protective clothing ensembles. Information on some items of this equipment is given in the following paragraphs. This information is only introductory and you should determine the type of protective clothing available and make certain you learn its purpose and how to use it. Your general health, and in fact, your very life, may depend on your knowing how to use the equipment available. Four very important aspects of behavior are essential when working in a hazardous area, or with hazardous equipment. These are:

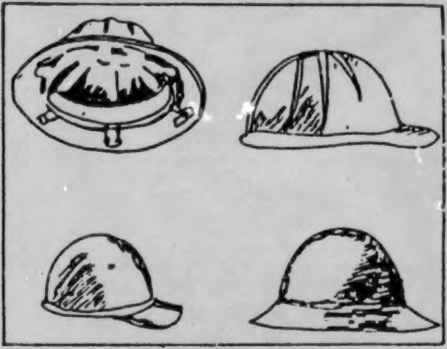
- Be able to recognize the hazard present.
- Understand what the hazard means to you.
- Know what safety equipment is available.
- Know how to use the available equipment.

Earplugs - This is about as simple a safety device as you will ever see; however, don't let its simplicity detract from its value. Expect to use these without fail when working in an area where the noise level is continuously high, such as a diesel powerhouse. It is important to realize that sound of moderate intensity, encountered for prolonged periods, can be as injurious to your hearing as high intensity sound encountered for a short period of time. The very best thing to do with earplugs is to keep them clean and use them. In some cases, ear muffs are provided as extra protection for the ears.

Gloves - Gloves are required for protection in many types of jobs. Locate the safety gloves in your area and use them. For the most effective use, you must know which type of glove to use in each instance, and you also must know the proper care of these items. Various types are supplied for electrical work, handling extremely cold or hot items, handling various chemicals, and for general physical protection of your hands from bruising, cuts, scratches, etc.

Eye and Face Protective Devices. If any one item of safety equipment could be described as the most important, it would probably be the eye protective equipment. It only takes a very minute piece of foreign material to permanently damage your eyes and cause you to lose your sight. To protect your eyes, determine the protective glasses, goggles, or shields required for each particular job or area, and wear this equipment.

Safety Hats. Hardhats or skull guards are designed to protect your head from falling or flying objects. Mose safety hats are water resistant, nonconductors of electricity, and will resist fire. They are available in a variety of sytles. Shown are several types of Air Force approved safety hats.



Types of Safety Hats

Since the hat is designed to protect your head, the one offering the most head protection is the one with a full brim. Once you receive your hat, take the time to adjust it properly. Proper adjustment provides for at least 1 1/4 inch of space between the top of your head and the inside crown of the hat. This space is to provide a cushioning effect in event something strikes the hat. Some important items to consider in the use of safety hats are given below.

- Never wear a metal type hardhat around electrical hazards. This is only common sense, since metal is a conductor of electricity.

* Never drill airholes in your hardhat. If it does not already have airholes, do without them as any you drill may cause the material to crack badly.

* The most important thing about safety hats is to be sure to wear them in the designated areas. They are absolutely worthless if you don't wear them.

A good safety program is designed to prevent accidents, and don't ever forget that most accidents can be prevented. Your part in this safety program is to become familiar with the causes of accidents and to follow the prescribed rules and precautions to prevent them. Some of the conditions which breed accidents are poor housekeeping, horseplay, improper use of tools and equipment, nonobservance of warning signs, and lack of an adequate fire prevention program. Of course, there are many other causes, among these are cases of personnel working with unfamiliar equipment or material. Therefore, to prevent accidents, it is necessary to know as much as you possibly can about the equipment and materials you come into contact with. In your job you will be working with, or near, such items as mechanical equipment, electrical equipment, liquid and compressed gases, acids, and alkaline materials. Take the necessary time to personally learn as much as you possibly can about the equipment around you. Manuals, pamphlets, technical sheets and commercial texts are available from which to learn this material.

When it comes to the maintenance of electrical equipment, this type work should only be performed by those personnel who are fully qualified. The person who maintains electrical equipment must be thoroughly familiar with the circuits and must be safety conscious at all times. He should work on an energized circuit only when it is absolutely necessary; he must use the proper safety equipment and take the necessary precautions to assure complete protection against electrical shock. Remember, electricity always conforms to certain laws of physics. You must treat it with the proper respect; otherwise, your experience in this field may suddenly be terminated.

Soft Solder, Silver Solder and Sil-fos. One of the most important aspects in attaining skills required in soft soldering, silver soldering and silver brazing is that you learn and observe all safety rules that apply to this operation. Therefore, we will begin this presentation with a review of these safety rules as they apply to these competencies.

1. You should always wear suitable, protective clothing; clothing that is tight fitting and will not become entangled in the torch, the hose, your work or come in contact with the flame from the torch.

2. You should always keep a safe, clean work area.

3. Make sure that there are no flammable materials near.
4. Do not weld in the vicinity of explosive materials or near carbon tetrachloride.
5. Always make sure that you have enough ventilation to give three or four complete changes of air per hour and please note that some silver soldering alloys contain cadmium. Cadmium free alloys should be purchased whenever possible. Oxidized cadmium is very toxic.
6. Be sure that you handle all pressurized cylinders with care and take note of the fact that acetylene can explode upon impact under pressure of 15 p.s.i. or more.
7. Do not use oil or grease on any oxygen or acetylene connections.
8. Never open the tank valve until you are certain that the regulator valve is closed.
9. Never open the tank valve with a hammer.
10. Never hammer on oxygen or acetylene regulators.
11. Do not light a torch with a match or an open flame. Use the striker provided.
12. Before lighting the torch, be positive that the hose, tank or any inflammable material will not be exposed to heat, flame or sparks.
13. Be aware of high acetylene pressure. Never use acetylene gas when the pressure is greater than 15 p.s.i.
14. Never turn the regulator screw in tight as this spoils the diaphragm.

NOTE: If the hose pressure drops, check tank pressure at the tank gauge. The tank is probably empty.

15. Be careful not to hold the welding tip too close to your work as this may cause the tip to get hot and result in flashback in the torch.
16. A hot tip or handle is caused by the burning of oxygen and acetylene inside the tip or the handle and this is a dangerous situation that should be repaired immediately.
17. Never use a torch that leaks, never leave your torch burning unattended and never leave the torch valve open.
18. Do not use the torch for a hammer, crowbar, wedge, prybar or for any purpose other than welding and do not use a cylinder, even when empty, as a roller.

19. Do not store cylinders in a room where the temperature is more than 80 degrees.

20. Never attempt to weld a closed or jacketed tank, vessel, or container without a vent hole for air. Even with a vent, great care should be taken not to get gas in the tank. If for any reason, you should get gas in the tank, be sure to aerate the tank.

21. Always use a regulator on air acetylene torches.

22. Release the pressure on the regulator screw by turning it counter-clockwise before opening the cylinder valve.

23. Stand to one side of the regulator while slowly opening the cylinder valve.

24. Secure all cylinders to table legs, bench legs, dolly or something to prevent them from being knocked over.

25. Do not use a torch on a closed container that contains pressure.

26. Never use oxygen as a substitute for compressed air and keep heat, flames and sparks away from all combustible materials.

Arc Welding

1. Never use welding machines which are not properly grounded. Ground all power circuits to prevent accidental shock. Stray current can cause a fatal shock. Do not ground the welding machine to any pipes which carry gases or flammable liquids.

2. Check welding cables frequently. Do not overload the capacity of the cable. Do not use cables which have breaks in the insulation. Be certain that all cable connections on the machine are tight. Overloading the cables will cause them to overheat and create a fire hazard.

3. Check the electrode holder frequently. The jaws in the electrode holder should be kept tight. The gripping surface of the jaws must be clean to insure a tight hold on the electrode. Use only fully insulated holders. Never touch two electrodes together when they are connected to two different machines: the operator can receive an electrical shock and the machines can be seriously damaged.

4. The polarity switch on the welder is provided to change the electrode from reverse polarity to straight polarity. The polarity switch must never be operated while the machine is under a welding load. Operate the switch only when welding has stopped. The operator who throws the polarity switch while the welding circuit is in use can be seriously burned.

5. Never weld on containers which have held explosive or combustible materials.

6. Never weld in confined spaces without adequate ventilation, and do not weld near an explosive atmosphere.

7. Do not weld where even small amounts of vapors from solvents are present. Some solvents decompose to form phosgene gas (a deadly poisonous gas).

8. Electricity can be a killer. Before checking any welding machine, open the power circuits. The welder should never try to make repairs on a welding machine unless he or she is a fully qualified electrician.

9. Do not touch any exposed or noninsulated parts of cables or clamps.

10. Do not work in a damp area unless insulated from shock. Striking an arc when feet are wet can cause electrical shock.

11. Do not use a cracked or defective helmet. The filter glass in the helmet provides eye protection from ultraviolet and infrared rays. Cracks in the lens allow these harmful rays to contact the eyes. The use of clean, clear lenses provides a method of cutting down on eyestrain.

12. Never look at an electric arc without eye protection. The intense light and the infrared and ultraviolet rays are harmful to the eyes.

13. Dark colored clothing helps to protect the body from ultraviolet rays.

14. Wear protective clothing when making out-of-position welds.

15. Any equipment which is operated by power can be dangerous. Grinders, drills, sanders, saws, electric welders and all other power tools can cause severe injury or even death.

16. Never do any grinding, weld slagging or heavy hammering without eye and face protection.

17. Do not leave materials or equipment lying on the floor. Clean up the work area. Take care of all safety hazards as soon as they are observed.

18. Do not use defective equipment.

19. Never strike an arc without warning people who are near and liable to see the arc flash.

20. Be alert to the dangers of fire. A small fire is easy to handle; a large fire can be disastrous. Know where the fire

extinguishers are and learn how to use them. Combustible material should not be within 35 feet of the welding operation.

21. Wear heavy shoes, preferably those with steel toes.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

UNITS OF MEASURING AND MEASURING DEVICES

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

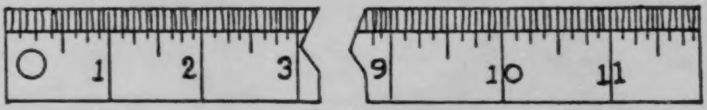
UNITS OF MEASURING AND MEASURING DEVICES

LINEAR RULES

There are two basic rulers which are most frequently used. They are the bench rule and the folding "zig-zag" rule.

BENCH RULE

The bench rule is usually one foot in length with sixteenth-inch graduations. It is mainly used to measure short distances--for instance, to saw short pieces of wood or to mark locations on wood to determine where nails, screws, or other pieces of wood are to be installed.



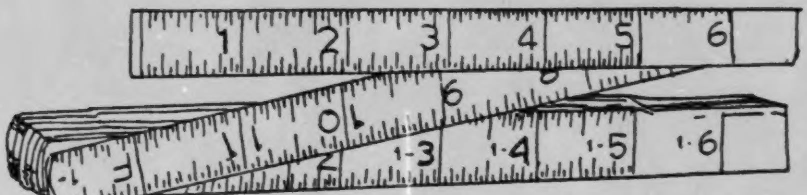
Bench Rule.

FOLDING RULER

The wooden folding (zig-zag) ruler is used most often in the six-foot length. It is made of lightweight wood with metal folding hinges and will fold to a size small enough to fit into a pocket or tool pouch.

A folding ruler is very handy and can be used as a one-man tool to lay off long or short measurements. It is also stiff enough to measure across horizontal openings.

When using the folding rule, care must be taken to obtain as accurate a measurement as possible because the hinges tend to become loose after much use. The folding rule is not considered to be as accurate as the tape measuring devices.



Folding Ruler.

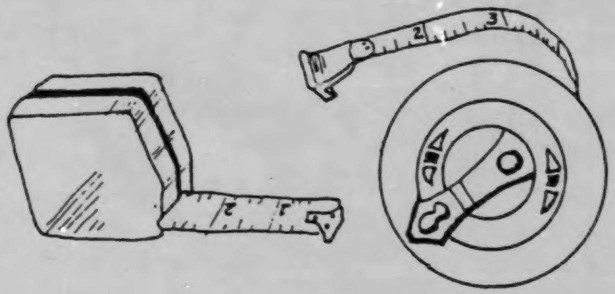
TAPE MEASURES

Tapes are used for general and precision measuring and are considered accurate to within 1/64 of an inch. Measuring which a carpenter does is usually to an accuracy of 1/16 of an inch.

When using tapes, select the size of tape which is long enough to do the job. Place the end of the tape at the beginning of the measurement, and then draw the tape in a straight, taut line parallel to the surface measured.

The smaller tape in Figure below is usually six feet in length. The larger tape can be of varying lengths, up to fifty feet.

Measurements are defined in whole feet, inches, and then fractions of an inch. For example: 4'8-3/16".

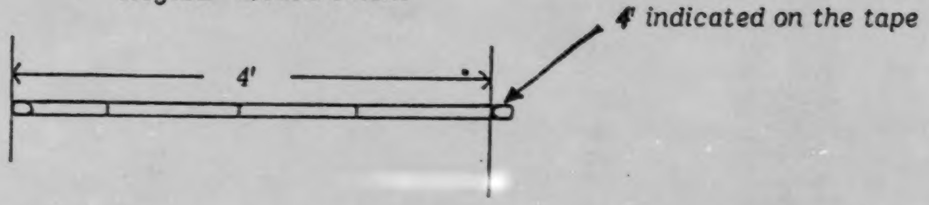


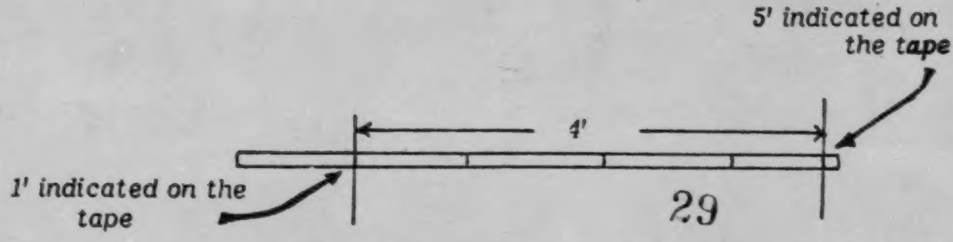
Tape Measures.

"CUT-A-FOOT"

When making a measurement, carpenters sometimes use the term "cut-a-foot". This means: instead of starting the tape at its beginning, the measurement is started from the one-foot mark of the tape. Therefore, when measuring a length of 4', the four-foot distance would be marked at the 5' mark on the tape.

Regular measurement





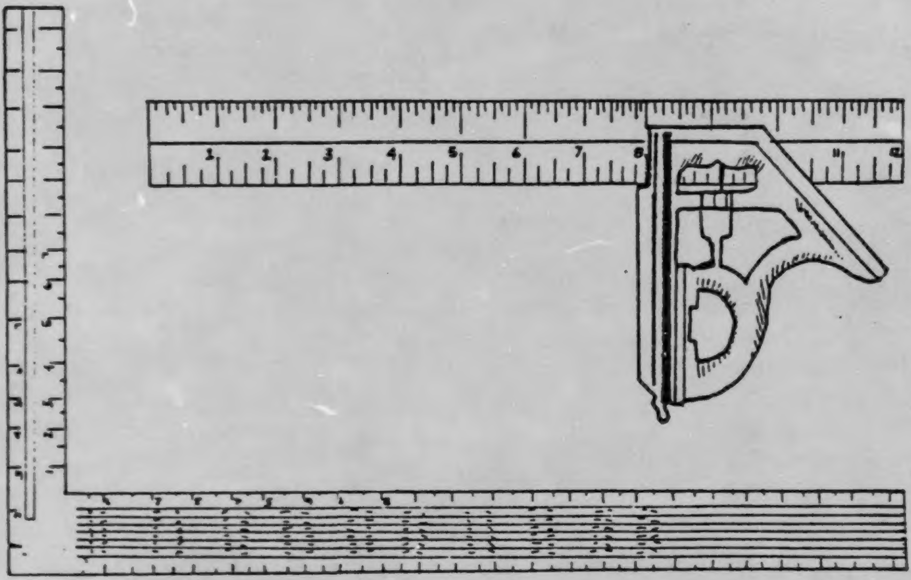
Cut-a-Foot measurement

SQUARES

There are two types of squares used most frequently by a carpenter. They are the framing square and the combination square.

FRAMING SQUARE

The framing square has a 24" blade on one side and a 16" tongue blade on the other. There are number tables stamped on the blade which are used for marking angles for rafters and braces. General use of the square is for framing procedures for layout of walls, partitions, and braces.



Framing Square and Combination Square

COMBINATION SQUARE

The combination square has several functions. It has a twelve-inch blade with an adjustable head. By adjusting the head, various lengths can be marked off. The head also contains a leveling bubble, as well as a side which is used to measure 45^0 angles. Generally, the purpose of the combination square is to square, measure and level.

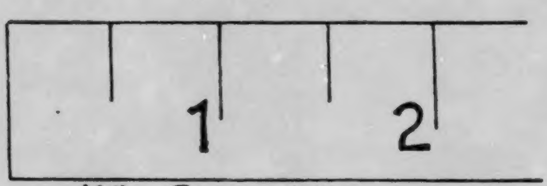
TOOL CARE

Steel squares, steel tapes, and tape rules should be kept clean and coated lightly with oil to prevent rusting. An occasional drop of oil on the joints of a folding rule is also beneficial for ease of operation.

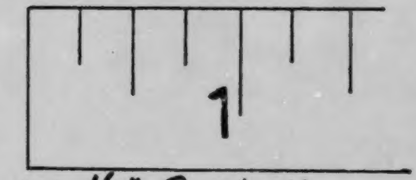
READING A RULE

When a ruler or tape measure is layed out properly it becomes possible to obtain an accurate measurement. A knowledge of reading the rule is required to interpret the graduation marks which appear on a measuring device.

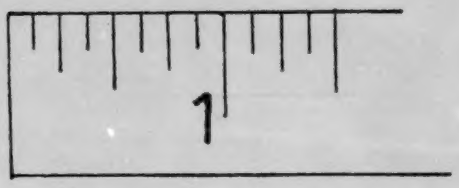
Generally, a carpenter makes measurements within 1/16 of an inch accuracy. Most rules are graduated in 16th of an inch. The figures below describe the graduations on a rule. Illustration D gives a total picture of the graduations within one inch of measurement.



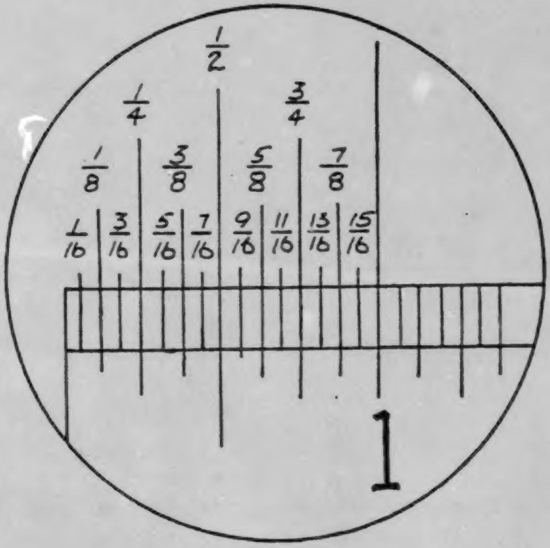
(A) 1/2" Graduations



(B) 1/4" Graduations



(C). 1/8" Graduations

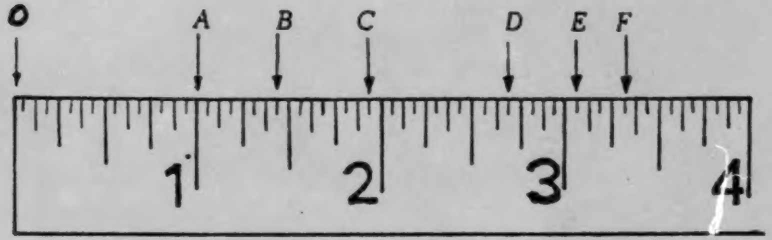


(D) 1/16" Graduations

Graduations of a Rule.

PRACTICE IN READING A RULE

Find the following measurements. (Use Figures on page 4 as a guide.)



Read all measurements beginning with zero.

A. ____________ D. ____________

B. ____________ E. ____________

C. ____________ F. ____________

ANSWERS

A. 1"	D. 2-11/16"
B. 1-7/16"	E. 3-1/16"
C. 1-15/16"	F. 3-5/16"

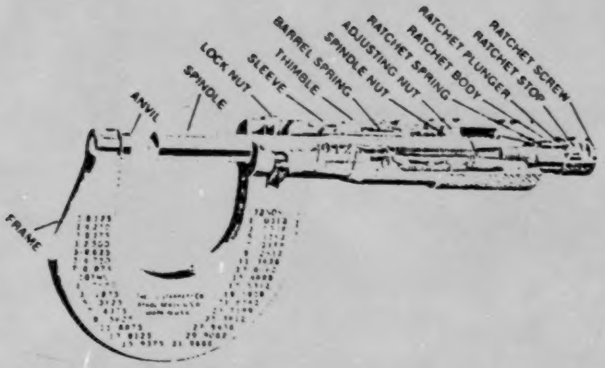
PRECISION MEASUREMENT

Micrometer measuring devices are the most commonly used instrument in measuring dimensions of materials. Correct use of these instruments is absolutely essential to making and inspection of component parts, specifically machined parts.

These are precision instruments and must be handled carefully. Procedures for cleaning and maintenance is included with each of these instruments upon purchase.

Before one can use an outside micrometer, clean anvil and spindle is essential and calibration must be checked.

Study this graphic and learn to identify each component part.



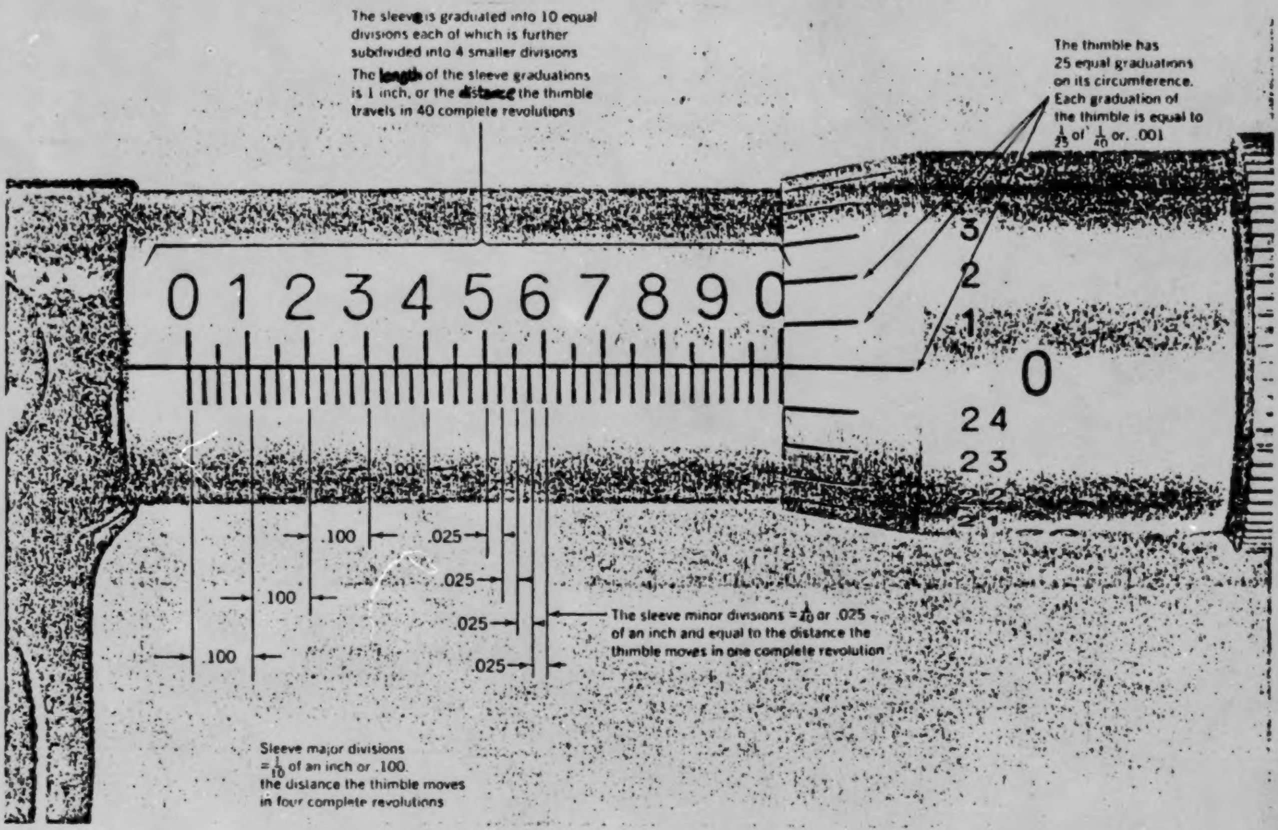
1. Clean the contact surfaces with a clean piece of paper by screwing the spindle down until slight pressure is placed upon the paper. Pull the paper out. Select another area of the paper and repeat the process.

2. Using the ratchet stop or friction thimble, screw the spindle down to contact with the anvil and check for 0 (zero) reading.

3. Since there are many manufacturers of micrometers, if calibration for zero reading is required, follow directions for this task as provided by the manufacturer.

4. Micrometers are usually used for measurements requiring dimensions expressed in decimal form. The inch micrometer is quite reliable to measure dimensions with a tolerance of ± .001 inch. If closer tolerances are required, the vernier micrometer is used and it will be covered later in this module. When measuring dimensions expressed in three place decimals think in terms of thousands of an inch. For example, .250 would be expressed as 250 thousandths of an inch.

The sleeve of the inch micrometer is graduated into 10 major divisions. Each major division would represent 100 thousandths of an inch. Each major division is divided into 4 minor divisions, thus each minor division represents 25 thousandths of an inch. The spindle has threads with a pitch of 40 (40 threads per inch), therefore, 1 turn of the spindle moves it 25 thousandths of an inch. Since the thimble is equally divided into 25 equal graduations, each graduation represents a spindle movement toward (or away from) the anvil of 1/1000 of an inch.



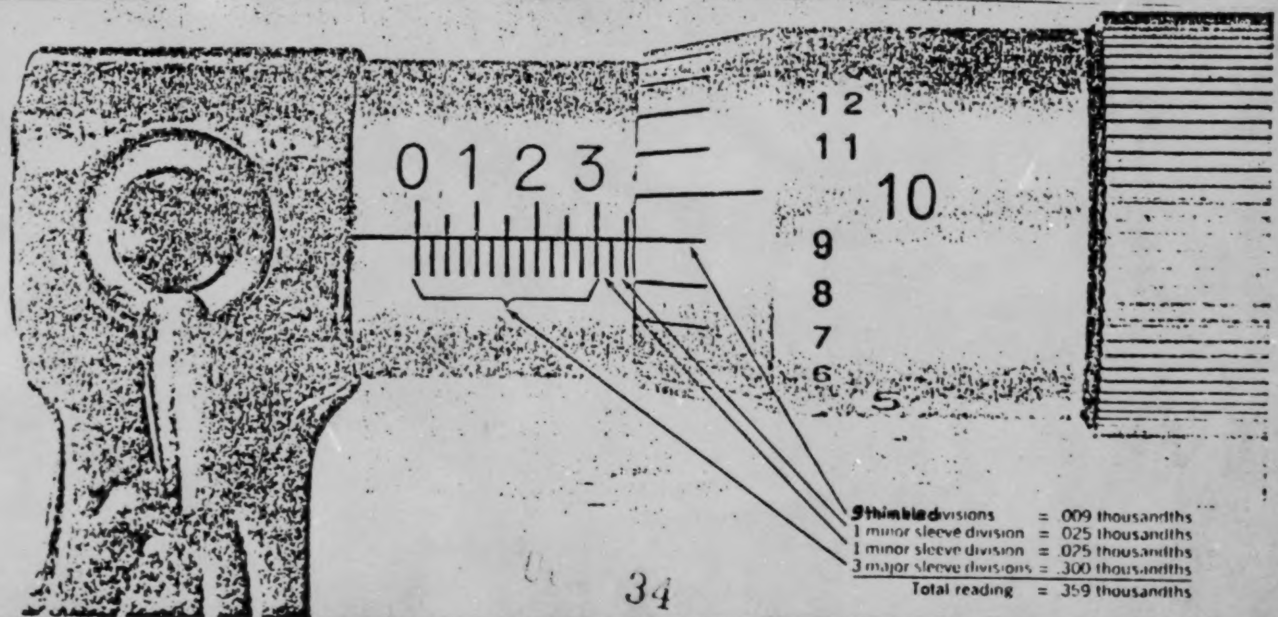
The sleeve is graduated into 10 equal divisions each of which is further subdivided into 4 smaller divisions

The length of the sleeve graduations is 1 inch, or the distance the thimble travels in 40 complete revolutions

The thimble has 25 equal graduations on its circumference. Each graduation of the thimble is equal to $\frac{1}{25}$ of $\frac{1}{40}$ or .001

The sleeve minor divisions = $\frac{1}{40}$ or .025 of an inch and equal to the distance the thimble moves in one complete revolution

Sleeve major divisions = $\frac{1}{10}$ of an inch or .100, the distance the thimble moves in four complete revolutions



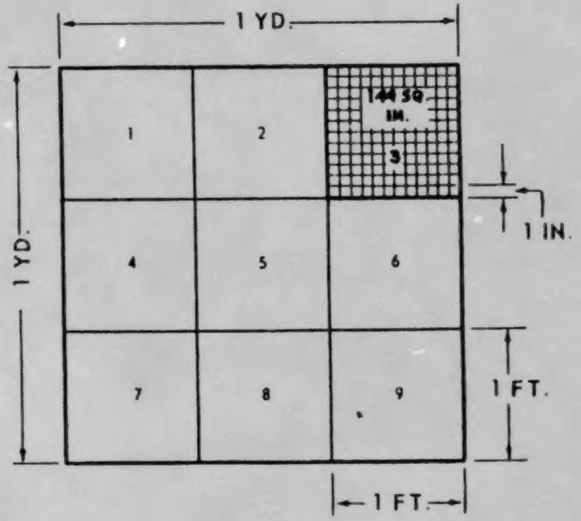
9 thimble divisions = .009 thousandths
1 minor sleeve division = .025 thousandths
1 minor sleeve division = .025 thousandths
3 major sleeve divisions = .300 thousandths
Total reading = .359 thousandths

One final note on the use of the outside micrometer. Accurate use of this instrument is a matter of "feel". When you calibrate your instrument, remember to use the same "feel" (pressure on thimble or ratchet stop) when measuring parts or materials and your measurements will be very close. Practice will make perfect in the use of this tool.

AREA MEASUREMENT

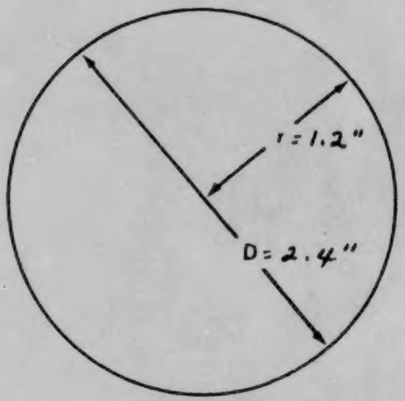
There are many other shapes of objects in which volume may be calculated such as cones, parallelograms, trapezoids, polygons, etc. However, the cylindrical and rectangular volumes are the most common.

The measurement of a rectangular area involves the measurement of two dimensional space, and the area of an object is found by multiplying its length x its width. For example, the width of a tabletop is 3 ft. and the length of the table is 5 ft. Therefore, the area of the tabletop is 3 x 5 or 15 square ft.

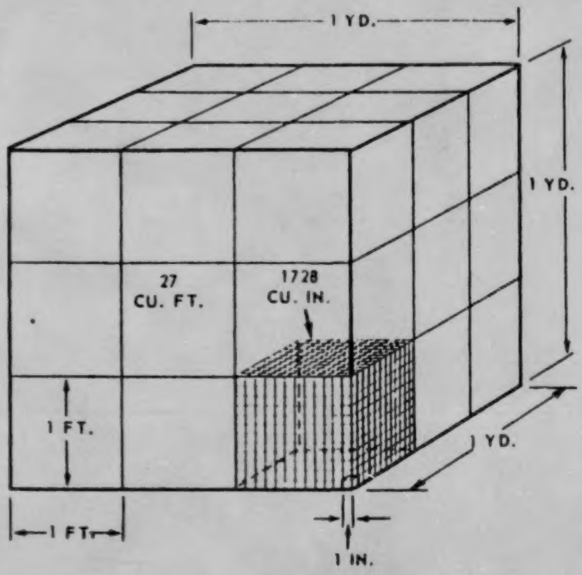


The area of the plane surface shown above is 1 yard x 1 yard, or 3 ft x 3 ft, having an area of 9 square ft. However, frequently we need to know the number of square inches involved in an area. In the frame shown each of the 9 square ft measure 12 inches x 12 inches. Therefore, block number 3 contains 144 square inches, that is, 12 x 12 and the number of square inches contained in this 2 dimensional figure 3 ft x 3 ft would be 144 x 9 (1296 square inches).

We also need to be able to measure the area of circular objects. The area of a circle is equal to πR^2. The radius is 1/2 of the diameter of a circle. When the diameter is known, divide the diameter by 2 resulting in the radius. The square of the radius x π equals the area of the circle. Remember the symbol R is always equal to 1/2 the diameter of the circle. Therefore, this formula may also be expressed as area equals π x D divided by 4. The diameter of the circle shown on next page is 2.4 inches. Therefore, the radius is 1.2 inches. Radius^2 equals radius x radius or in this instance 1.44. 1.44 x 3.1416 equals 4.524. A circle with a diameter of 2.4 inches has an area of 4.524 square inches.

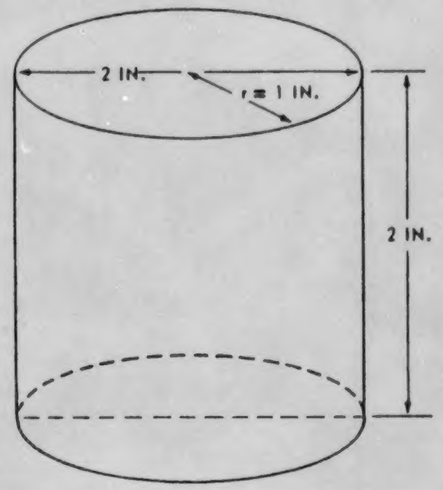


The method of calculating the volume of a 3 dimensional object is length x width x height. So the 1 yard x 1 yard x 1 yard cube that we see in the figure below would contain 3 x 3 x 3 or 27 cubic ft. 27 cubic ft. equals 1 cubic yard.



Looking at the small portion of this cubic yard, 1 ft x 1 ft x 1 ft and remembering that there is 144 square inches in 1 square ft., 144 x 12 results in 1728 cubic inches in 1 cubic ft. We are primarily concerned about cubic inches because most of the measurements concerning volume will be measured in cubic inches. Of course in determining the number of cubic inches in this cubic yard, we would multiply 1728 cubic inches representing 1 cubic ft., x 27 which is the number of cubic ft. whown in this 3 dimensional object to determine the number of cubic inches in a cubic yard.

The volume of a cylinder is equal to the area of the end multiplied times its length. Cylindrical dimensions are usually expressed in inches and decimals of an inch, such as 1.250 inches and not 1 1/4 inches. The volume of the cylindrical figure shown in this frame would be equal to the radius squared, 1 x 1 = 1 x π 3.1416 resulting in an area of 3.1416 x the 2 inch length equaling 6.28 cubic inches.



PRACTICE EXERCISE

Let us apply the skills that we have attained in the previous frames to the volume contained by a 12 inch length of 1 inch diameter copper tubing. 1 inch diameter copper tubing has a wall thickness of .05. Therefore, the inside diameter of the 1 inch copper tubing would be .9. The wall thickness .05 must be multiplied x 2 since the tubing has 2 wall thicknesses to be subtracted from its outside diameter. Thus, with a diameter of .9 the radius would be .45, (.9 divided by 2). $.45^2$ would equal .202. .202 x π would equal .636. The area of the inside diameter of a 1 inch copper pipe would be .636. Therefore, a 12 inch length of that copper pipe would have a volume of .636 x 12 or 7.632 cubic inches. One of the most important things to remember in determing volume is be certain that you match your units; inches with inches, feet with feet, etc. In this case we found the area of the 1 inch copper pipe being .636 cubic inches; therefore, to determine the volume of a 1 ft. section of this pipe, we multiplied it x 12 inches rather than 1 ft. What would be the volume of a 20 ft. section of pipe 1 inch in diameter? It would be 7.632 x 20, 152.640 cubic inches and if the requirement were that this volume be expressed in cubic ft. then we would divide 152.640 x 1728 which is the number of cubic inches in a cubic ft. resulting in a figure of .088 cubic ft.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

HAND TOOLS/POWER TOOLS AND FASTENERS

STUDENT MATERIAL

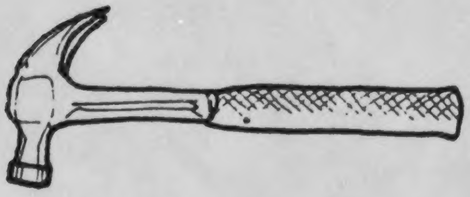
MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

HAND TOOLS/POWER TOOLS AND FASTENERS

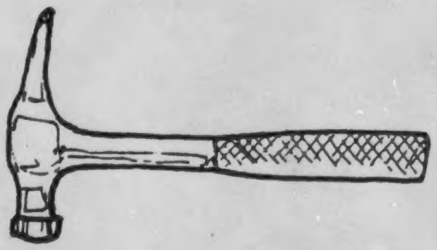
HAMMERS

Hammers are made in varying qualities. When tempered and properly heat-treated, they are stronger than ordinary steel and the head is able to take the impact of driving nails.

There are two hammer shapes available for general carpentry work: the curved claw and the straight claw. Both hammers can be used for pulling or driving nails, but the curved claw is more suitable for pulling nails. The straight claw hammer is used for prying wood apart because the claw permits it to serve as a wedge.

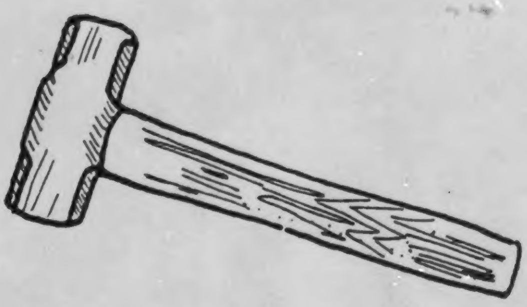


Curved Claw



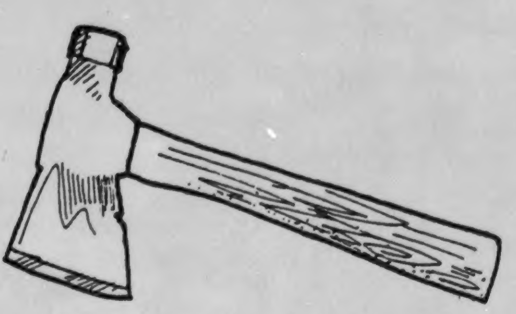
Straight Claw

Another type of hammer is the shop hammer. This is a large hammer with two identical heads and its size may vary between two and twenty pounds.



Shop Hammer.

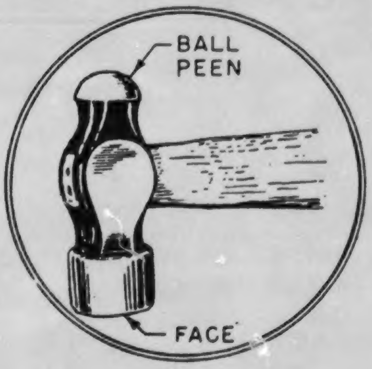
A hatchet is a tool which can be used for several purposes. It has a short handle with a sharp cutting surface on one side and a hammer head surface on the other. The head is used for driving nails, the slot on the side of the brace is used for pulling nails, and the sharp edge is used for sharpening stakes or splitting boards.



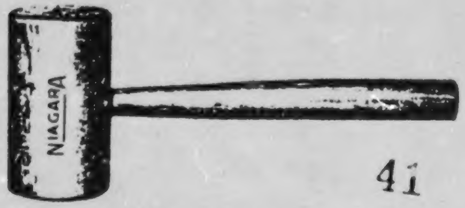
Hatchet.

Special hammers are designed for more specific applications and are used less frequently than those previously shown.

The ball peen hammer is used with pin punches, prick punches and riveting. It is available in sizes from 4 ounces to 2 1/2 pounds.



The mallet is one of the most abused tools because it is often used to perform operations for which it is not designed. Mallets are properly used where steel hammers would deface the work. A good grade of hickory or hard fiber mallet will last a long time if used in the correct manner on proper materials.

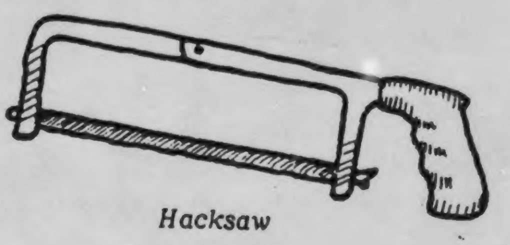


Mallet.

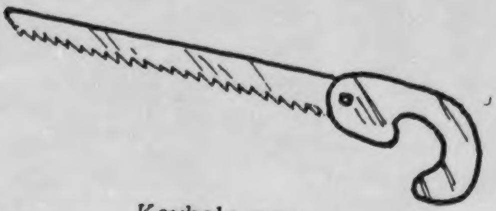
SAWS

Good sharp cutting tools are important to the carpenter. Saws must be kept sharp and free from rust if they are to cut properly. Three saws which are used most frequently are: the hand saw, the keyhole saw and the hacksaw.

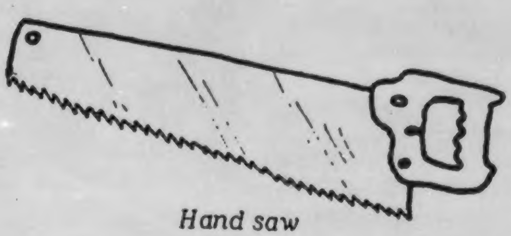
The hacksaw is used for cutting all types of metal parts and hardware; the keyhole saw cuts curves and round holes in wood; the hand saw is for general cutting purposes for all kinds of wood.



Hacksaw



Keyhole saw



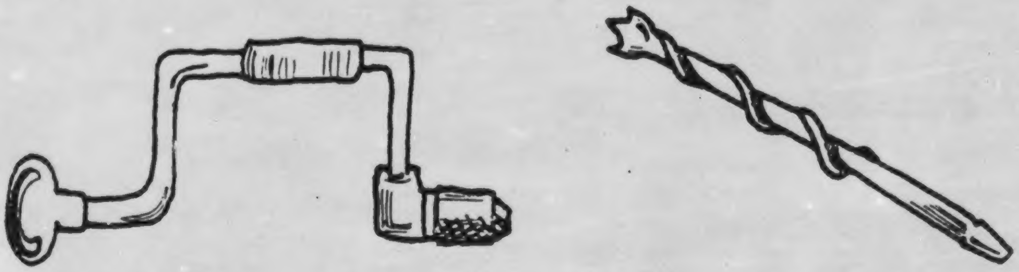
Hand saw

BORING AND DRILLING TOOLS

The carpenter's brace is used to hold and turn bits for boring holes in wood. The bit is held in place by a universal type chuck which can be adjusted to hold various sizes of bits.

There is a ratchet device on most braces which allows them to be used in confined spaces where a complete turn of the handle cannot be made. The size of a brace is determined by the diameter of the circle made by one revolution of the handle.

A wood (auger) bit is also shown below. This is used along with the carpenter's brace to bore holes.



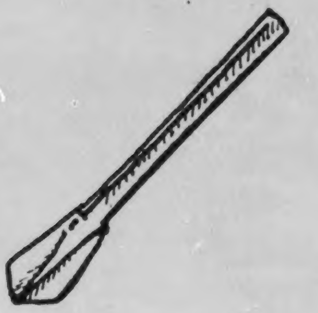
Brace

Wood Bit

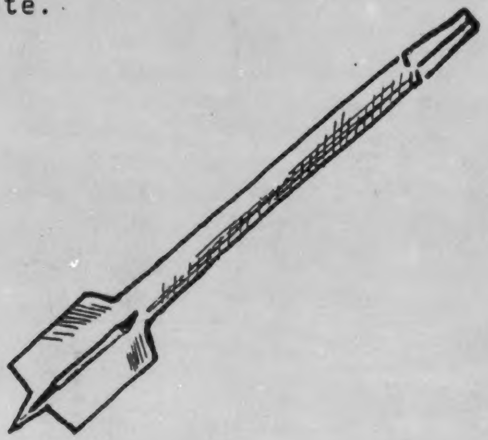
Carpenter's Brace and Wood Bit.

IV-S-40

Other types of bits are shown below. These include the speed bit and the star drill. The speed bit is used for drilling wood and is used with an electric hand drill. The star drill is used with a hammer for boring holes in concrete.

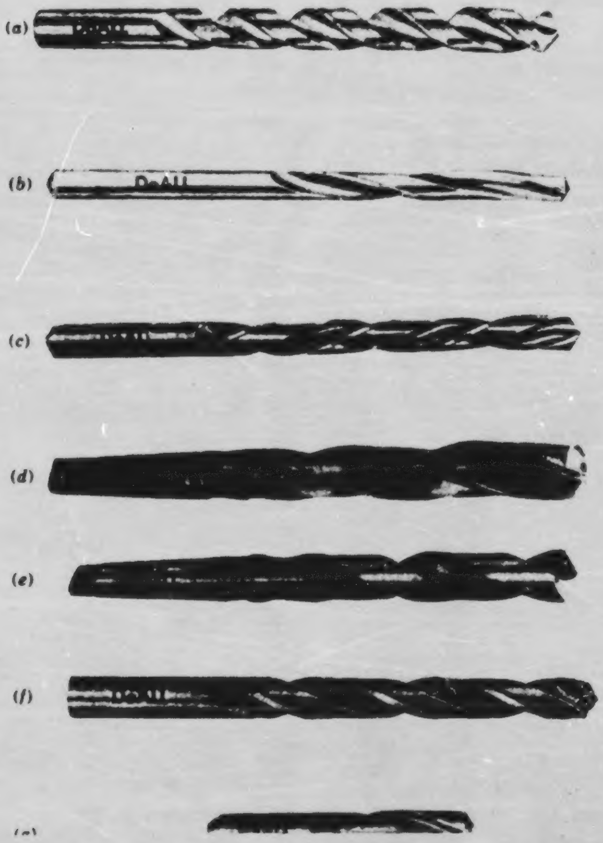


Star Drill



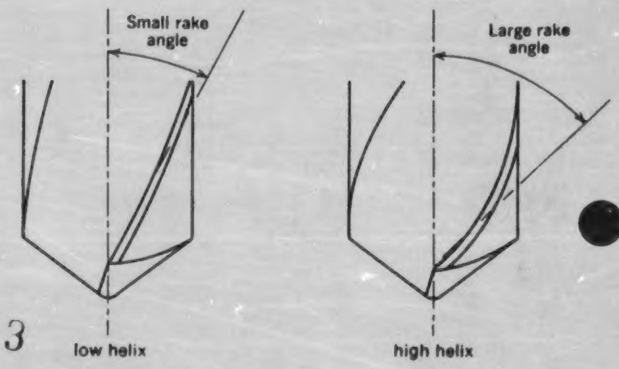
TWIST DRILLS

The twist drill is the most common type of drill bit used today. It is available in many sizes - from .010 inch to several inches in diameter. Also many configurations of flutes and rake angle make these drills suitable for many applications. The small rake angle is used for hard materials such as steel, while the large rake angle is used for soft materials such as aluminum or wood.



Various types of twist drills used in drilling machines (Courtesy of DoAll Company) :

- (a) High helix drill
- (b) Low helix drill
- (c) Left-hand drill
- (d) Three flute drill
- (e) Taper shank twist drill
- (f) Standard helix jobber drill
- (g) Center or spotting drill



LEVELING DEVICES

The purpose of leveling devices is to ensure that all structures are built in a straight and level manner.

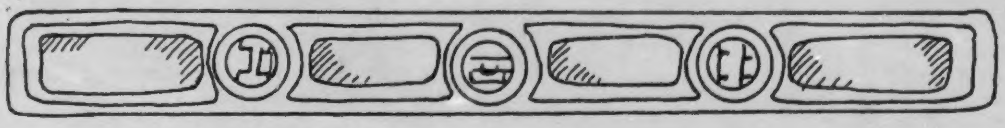
Leveling devices include: Carpenter's Level, Torpedo Level, and Plumb Bob.

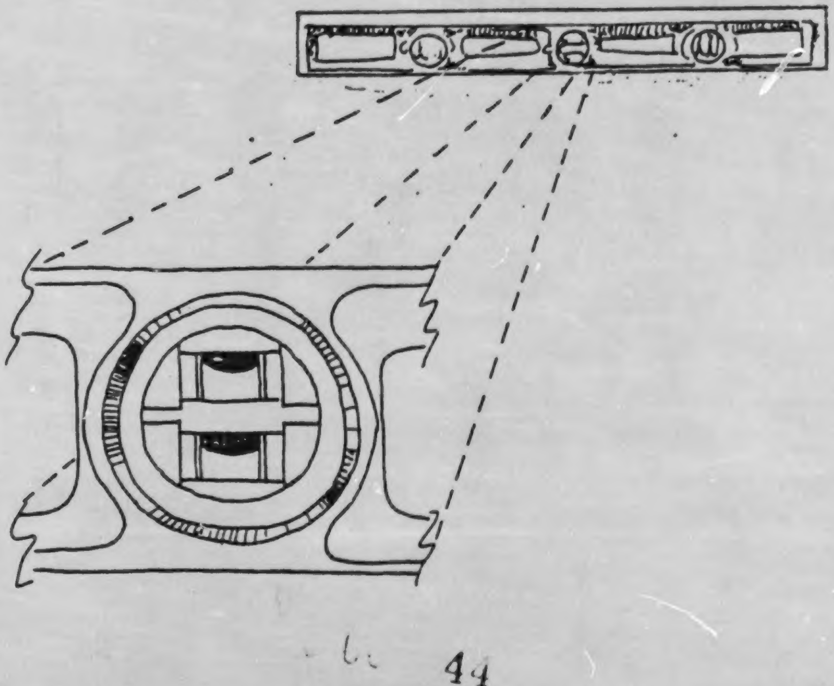
Carpenter's Level

The carpenter's level is a tool consisting of one or more glass tubes, each containing an air bubble and centering lines mounted in a frame of aluminum, wood, or iron. The glass tubes are set to allow leveling in horizontal, vertical, and 45^0 positions. A level is usually designated by its length, which is most commonly 18 inches or two feet. The main objective is to align the bubble to achieve a level surface.

For obtaining an accurate level, the bubble must be centered between the lines on the glass tube.

When an object is not level, the bubble moves in the direction of the higher side of the level. Therefore, to obtain a level surface, either lower the high side or raise the low side of the level.

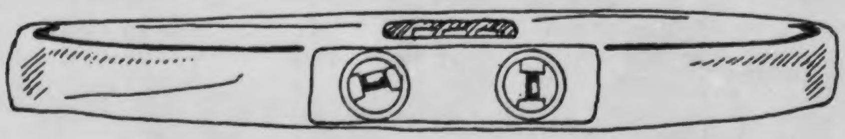




Torpedo Level

Another type of level is the torpedo level. It is a smaller version of the carpenter's level, but is is read in the same manner. The torpedo level is generally made of aluminum or wood and is nine inches in length. A torpedo level is also available with a magnetic bottom surface which allows leveling of a metal surface without having to hold the level on it.

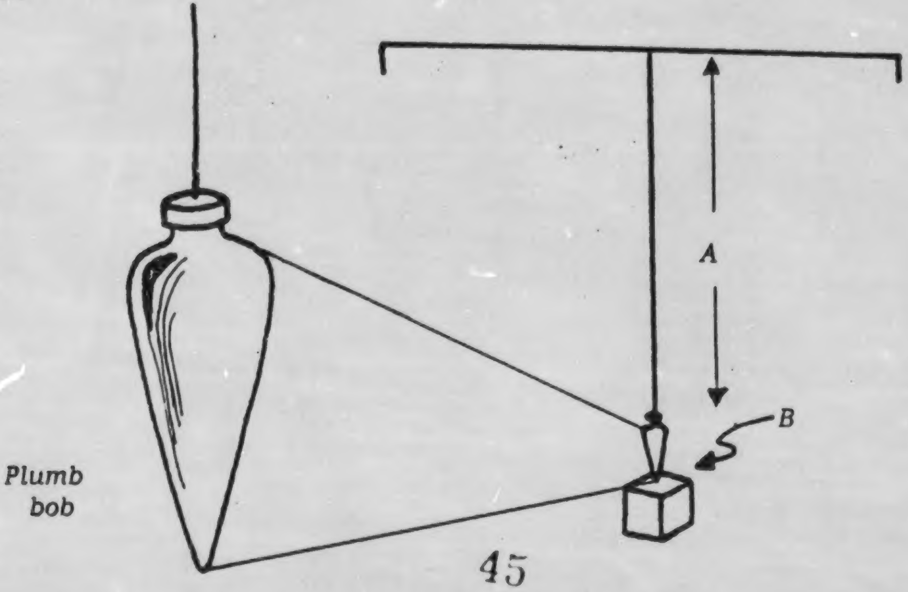
Because of its short length, special care must be taken when using the torpedo level. An accurate level reading can only be obtained when the level is placed on a smooth and clean surface.



Plumb Bob

The plumb bob is used to make certain that items of construction are plumb (vertically true). Carpenters use the plumb bob for measuring, marking, and transferring points of reference. There are many circumstances which require the use of a plumb bob, but generally it is used to measure from a centerline. Care must be taken to eliminate any sway of the plumb bob in order to obtain an accurate vertical line.

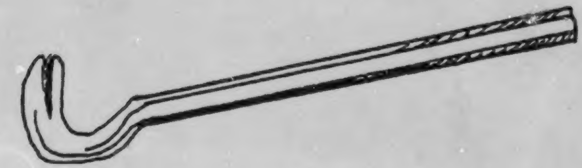
This illustrates the use of the plumb bob to measure from a center line to a point below it. The line (Point A) is vertical and the spot (Point B) is on a straight vertical line directly beneath the upper line.



Use of a Plumb Bob

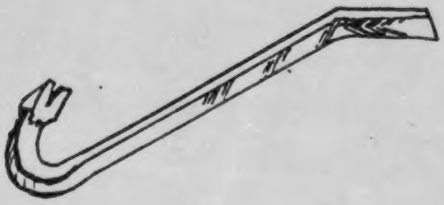
NAIL CLAW

The nail claw is used primarily for pulling large nails from wood.



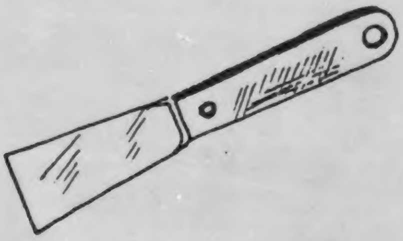
PRY BAR

The pry bar can be used for pulling nails, but is used primarily for dismanteling or wrecking.



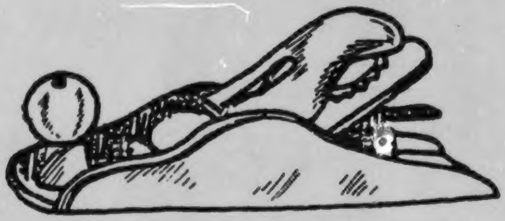
PUTTY KNIFE

A putty knife is used as its name implies - to apply putty. This is used mostly by a finish carpenter.



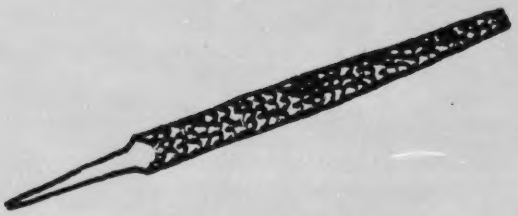
HAND OR BLOCK PLANE

The plane is used to smooth and remove high spots from wood.



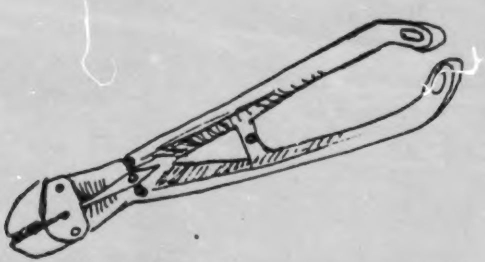
WOOD RASP

The wood rasp is a very basic tool used to smooth edges and surfaces of wood.



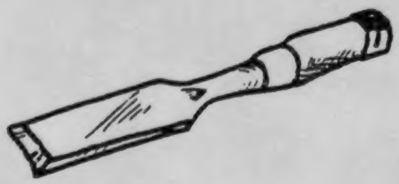
BOLT CUTTER

The bolt cutter is a very powerful tool and has the capability of cutting various sizes of bolts.



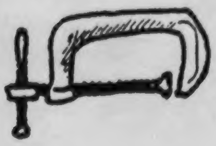
WOOD CHISEL

The wood chisel requires that a hammer be used in conjunction with it. The chisel cuts holes and grooves in wood and the size of cut depends on the size of the chisel.



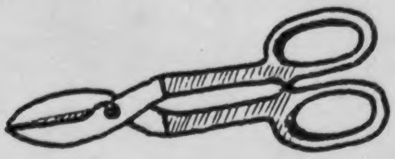
"C" CLAMP

The "C" clamp is used for clamping purposes and aids in alignment.



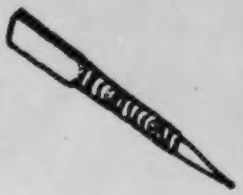
TIN SNIPS

Tin snips resemble scissors in principles of operation. Their application is in cutting thin sheet metal such as tin, galvanized sheets of material, and other metals.



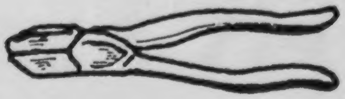
NAIL SET

The nail set is used to drive nails to a level which is below the surface of the wood. When this is done, putty is applied to the hole in order to obtain a level surface on the top of the wood.



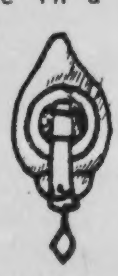
SIDE CUTTER PLIERS

Side cutter pliers can be used as a gripping device for small objects, but they are used primarily for cutting various sizes of small gauged wire.



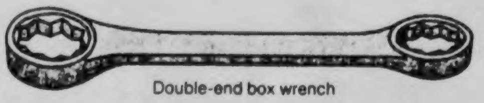
CHALK LINE AND REEL

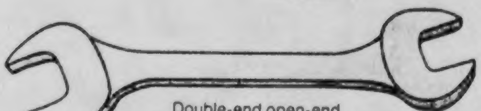
The chalk line and reel is a self-chalking line reel which enables a carpenter to lay out a straight line from one point to another. The case contains chalk and as the line is pulled out, it is coated with chalk. When a line has been established, the chalk line is stretched tight along the surface. The string is then picked up and released, allowing it to snap. The chalk will then be deposited on the surface in a straight line.

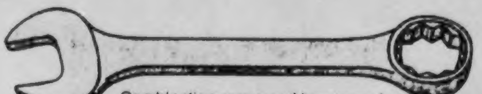


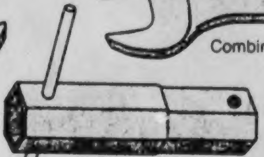
WRENCHES

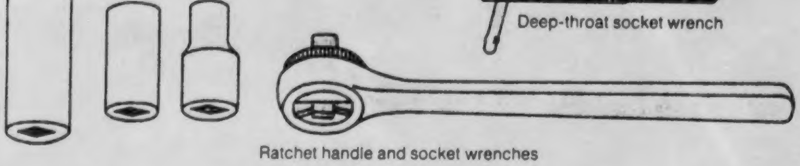
Wrenches grip not only nuts and bolt heads, but in special forms, other objects from pipe to spark plugs. In general, where a wrench cannot be applied over the end of the work, as in tightening a fuel line connection, an open-end wrench is used. The adjustable open-end wrench fits many sizes. Where a wrench can be applied from the end of the work, as in removing a nut, a box or socket wrench is used; it can operate in tighter quarters than an open-end wrench. The Allen wrench, sometimes called a hexkey wrench, fits the hexagonal recesses in various Allen-type screws and setscrews. For round objects such as pipe, the Stillson, or pipe wrench, is used. Its movable upper jaw tightens automatically as pressure is applied to the handle.

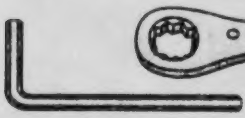

Double-end box wrench

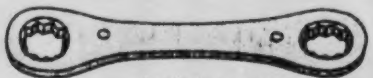

Double-end open-end wrench fits two sizes.

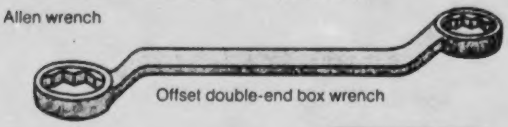

Combination open-end box wrench

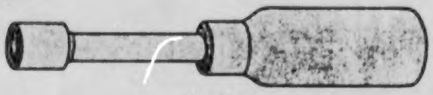

Deep-throat socket wrench

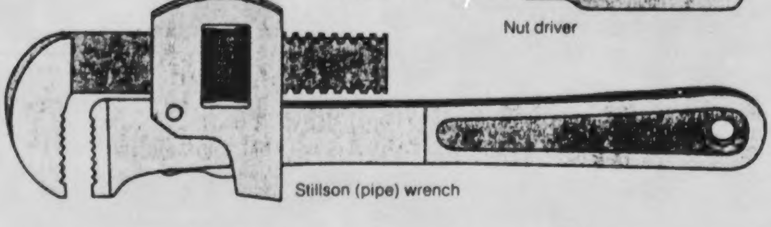

Ratchet handle and socket wrenches

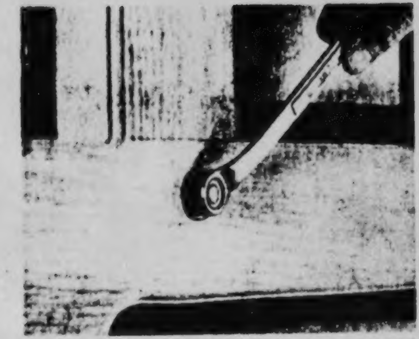

Allen wrench


Ratchet box wrench speeds work

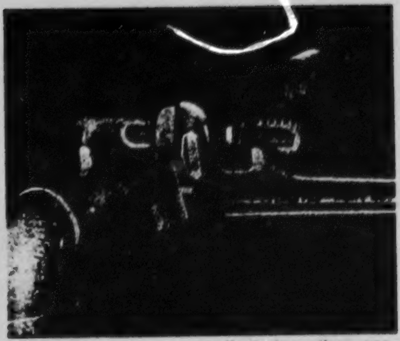

Offset double-end box wrench


Nut driver

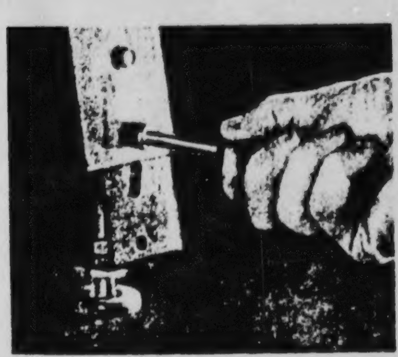

Stillson (pipe) wrench



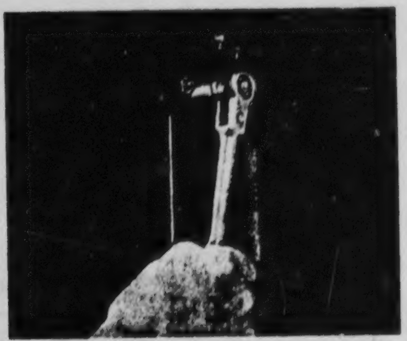
Box wrench has great strength, can be used where handle swing is limited to as little as 30°. All box wrenches are available double-ended or in open-end combinations.



Pipe wrench jaws are adjusted so they contact pipe surface with a knurled nut in the upper handle. When pressure is applied to the handle, the jaws tighten automatically.

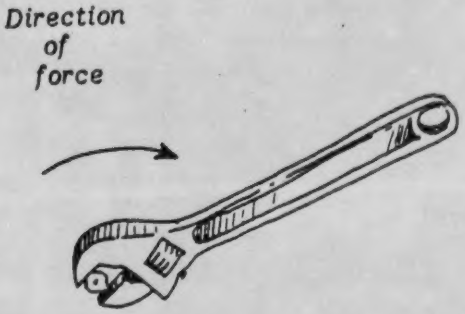


Nut driver is available in sizes to fit hex nuts from 3/16 to 1/2 in., some are self-adjusting from 1/4 to 7/16 in. Use the nut driver in the same way as you would a screwdriver.



Socket wrenches are available in sets ranging from as few as six pieces to more than 200. Ratchet fittings and universal joints multiply its range of uses. Handy for auto work.

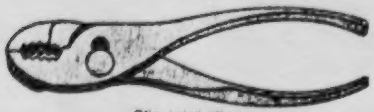
The adjustable (crescent) wrench has one adjustable lower jaw and one stationary upper jaw. It is used primarily for tightening and loosening nuts and bolts. When using the wrench, always place the wrench on the nut or bolt so that the force is being applied to the stationary part of the wrench.

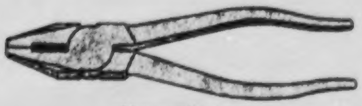


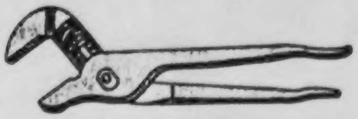
PLIERS

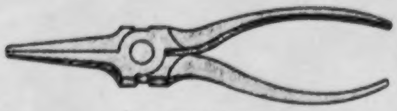
Types of Pliers

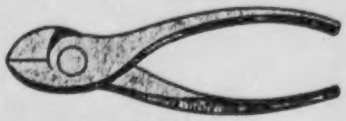
The familiar slip joint pliers are named for the two-position pivot that provides both normal and wide jaw openings. Broad-jawed lineman's pliers have side cutters which equip them for heavy-duty wire cutting and splicing. Channel-type pliers with multiposition pivots adjust for jaw openings up to 2 inches and will grip any shape. Long-nosed pliers are used to shape wire and thin metal, and often for cutting as well. Diagonal-cutting pliers have no gripping jaws and are used for cutting only. Also for cutting only are end-cutting nippers, which can snip wire, small nails and brads.

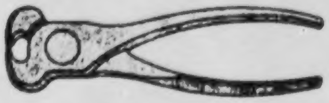

Slip-joint pliers


Lineman's pliers

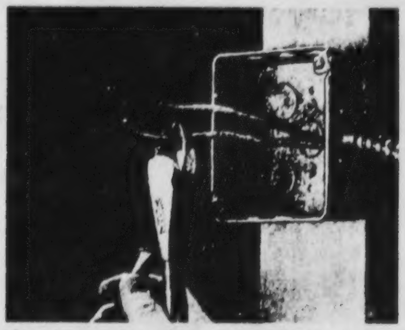

Channel-type pliers

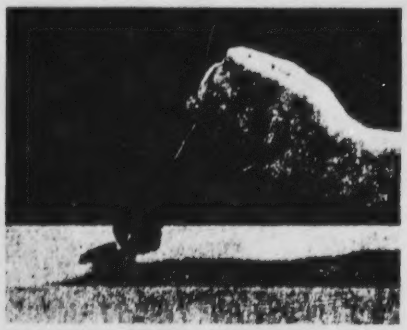

Long-nose pliers

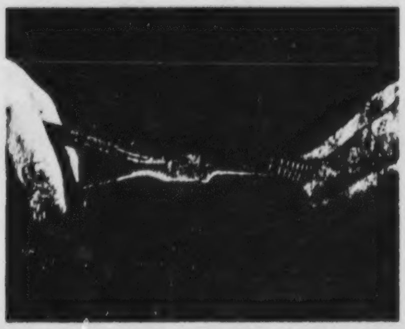

Diagonal-cutting pliers

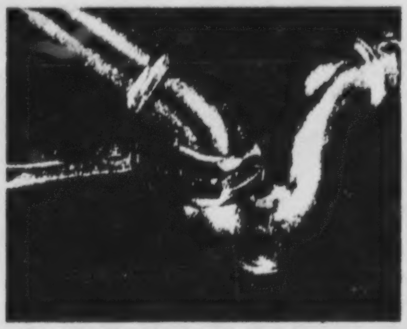

End-cutting nippers

Using Pliers


Diagonal-cutting pliers have hardened steel cutting edges for cutting wires, small brads.

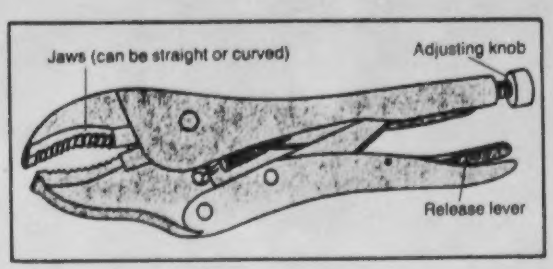

End-cutting pliers also have hardened cutting edges, are used to pull nails and cut wire.

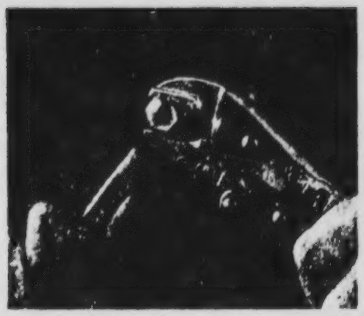

Long-nose pliers make terminal loops in wire, shape jewelry, insert small machine parts.


Channel-type pliers open wider than others, grip many shapes with long-handle leverage.

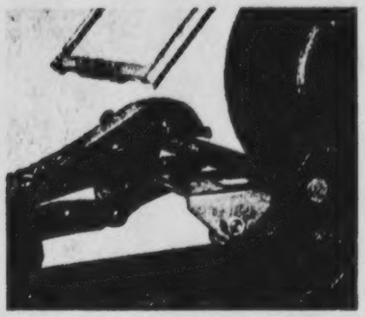
Combination Plier-wrench

The plier-wrench functions as pliers, wrench, or vise. When it has been set to the desired gap, adjustable compound lever action locks it, auxiliary lever releases it. For work on round objects, such as pipe, use the curved-jaw type.





Combination plier-wrench is set to approximate grip gap with adjusting screw, then locked onto work with handles. Lever action releases its grip.

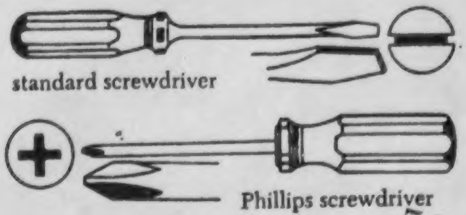


Plier-wrench, set to grip tightly, is handy for holding work against power grinding wheel. Point tool rest at wheel's center. Wear goggles.

This same tool will also protect your hands when you are using a star drill, by holding the drill in position. Keep plier-wrench close to drill point.

SCREWDRIVERS

There are many types of screwdrivers available, the two basic types being Phillips head and plain head. When using screwdrivers one rule of thumb is to use a screwdriver which fits the slot of the screw. If the blade is too big or small it will tear the screwhead. Also, wood screws require a wider blade than do sheet metal screws, so buy the type of screwdriver suited to the job.



POWER TOOLS

The power tools included are those which are used most frequently and require a knowledge about those tools by knowing what they are and what purpose they serve.

Special care must be taken and all safety rules must be followed when handling power tools because of the potentially dangerous aspects of electricity and air under high pressure. Always wear goggles or a face shield and, to prevent electrical shock, never stand in water when using electrical tools. Any adjustments which need to be made to the tool prior to operation are the responsibility of the person using the tool.

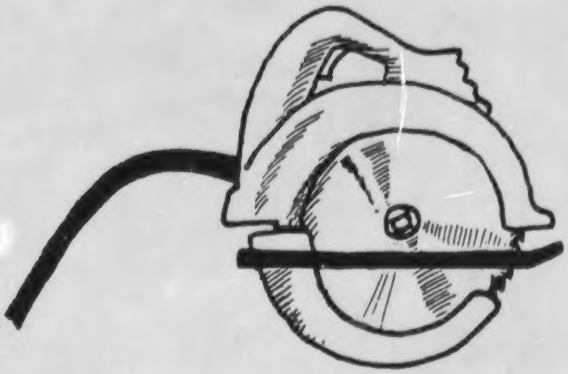
ELECTRIC SAWS

There are several electrical saws used by a carpenter. Some are portable and others are stationary. The portable saws are: electric hand (skill) saw, saber saw and reciprocating saw. The other floor-mounted saws include: table saw, radial arm saw and band saw.

Electric Hand Saw

This is also sometimes called a skill saw. It is a portable circular saw which has a wraparound blade guard to protect the user. Most electric hand saws are single speed and come in a variety of sizes.

The electric hand saw is a very convenient tool to use and is used quite frequently. This saw accounts for the majority of hand and finger injuries. Therefore, care must be taken to keep fingers away from the blade. Goggles or a face shield should be worn when sawing.



IV-S-52

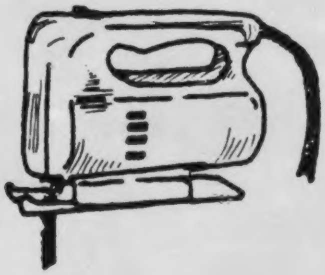
Saber, Reciprocation and Band Saws

The saber and reciprocating saws are used in smaller, confined areas where the larger electric saw cannot be accommodated and are also used for cutting curved and irregular patterns in wood.

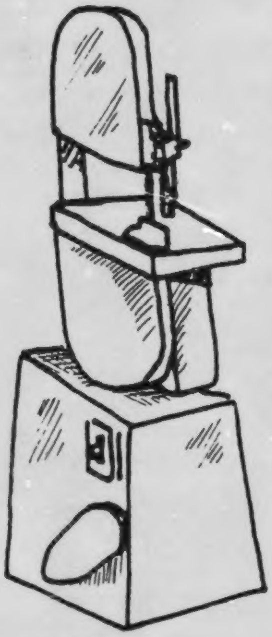
The safety **rules** which apply **to** the electric hand saw must also be followed when using these electrical saws.

The band saw is a stationary saw for cutting curved and irregular **patterns**.

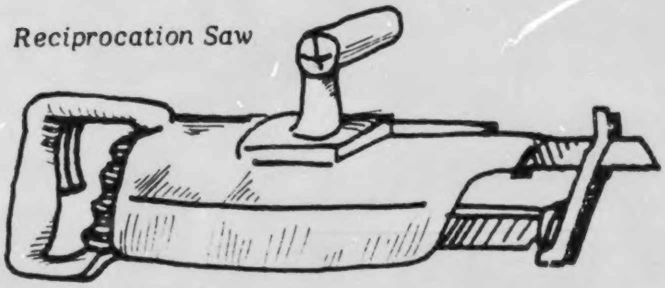
Saber Saw



Band Saw



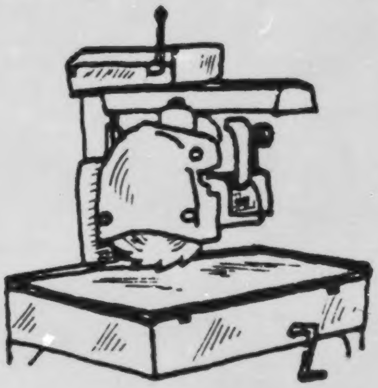
Reciprocation Saw

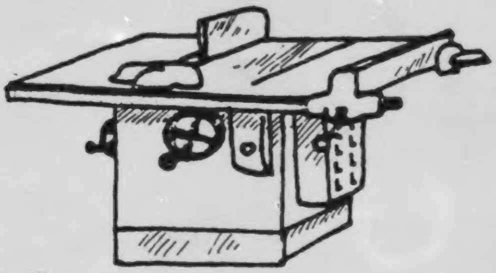


Radial Arm and Table Saw

These saws are floor-mounted and are capable of cutting a wide variety of lumber sizes. They can be used for crosscutting, ripping and mitering.

Care must be taken to keep out of the line of sawing, to keep hands and fingers clear, and to avoid forcing lumber into the saw blade.



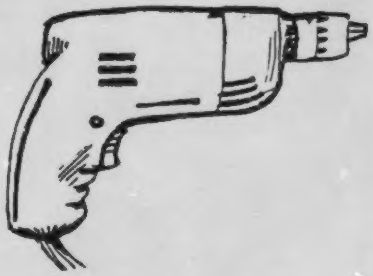


ELECTRIC DRILLS

Electric Hand Drill

The electric drill is possibly the most widely used power tool throughout the construction industry. It is available in many sizes, styles, and capacities. The size is determined by the maximum drill bit diameter which the drill chuck will hold. The 1/4, 3/8, and 1/2 inch drill bits are most commonly used.

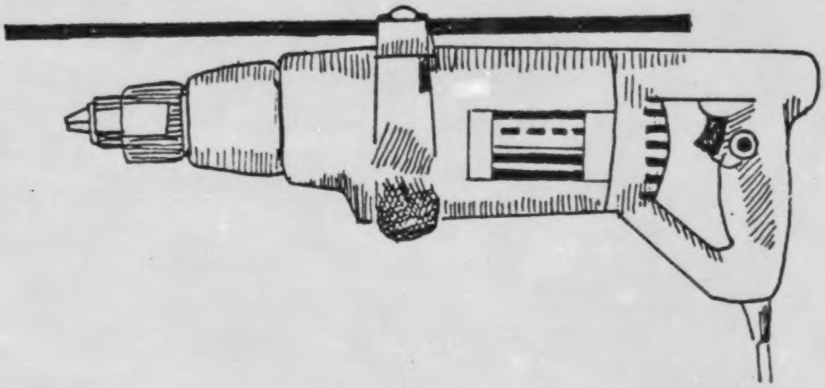
To install a drill bit, loosen the jaws of the chuck, slip in the shank of the bit, and then tighten the chuck with a key.



Power Masonry Drill

This is a tool which is designed primarily for drilling holes in masonry materials. The masonry drill bit is used in conjunction with it.

When using this tool, always follow the safety rules pertaining to electric tools.



FASTENERS

Nails

There are many types of nails, all of which are classified according to their size and use. Nails vary in size, weight, type of point, finish, and size and shape of the head. All normal requirements of construction are filled by one of the nail types described in this training manual.

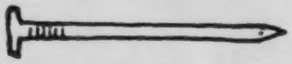
There are a few general rules to be followed in the use of nails. A nail should be at least three times as long as the thickness of the wood it is intended to hold. Two-thirds of the nail is driven into the second piece for proper anchorage.

Nails should be driven at an angle slightly toward each other so as to provide maximum holding power. Nails should also be driven across the grain as opposed to driving them with the grain.

TYPES OF NAILS

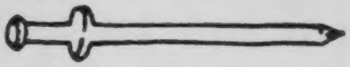
Common Nail

The common nail is used most frequently for construction carpentry. It is a steel nail with a flat head which provides a striking surface for a hammer. The various sizes of nails will be discussed on the following pages.



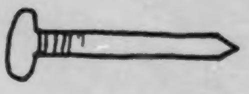
Duplex Nail

The duplex nail is considered to be a semi-permanent nail. It has two heads; the lower is provided so that the nail may be driven securely, while the upper head projects above the surface of the wood. The reason for this design is that the nail can be removed without difficulty. The duplex nail is particularly useful in the construction of concrete forms when the forms will eventually have to be dismantled, and the nails removed.



Galvanized Nail

A galvanized nail is similar in size to the common nail. The galvanized material, however, is resistant to rust. One of the common uses is for roofing nails.



Concrete Nail

The concrete nail is designed to attach items to concrete. It is sharp-pointed with ribs running the length of the nail and it is tempered for extra strength.

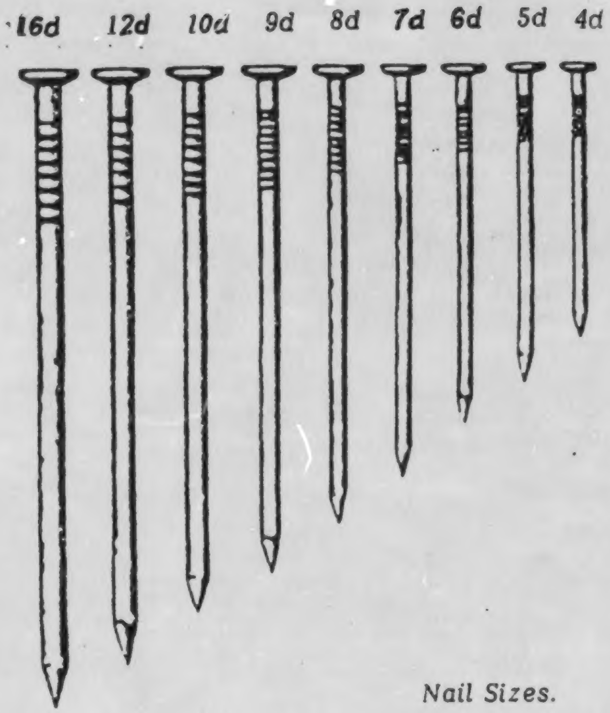
NAIL SIZES

Nail sizes are designated by the term "penny". This term designates the length of the nail (2 penny, 3 penny, 4 penny, etc.), and applies to all types of nails.

The "d" adjacent to the number of nail size is the accepted abbreviation for the word "penny". Therefore, a nail size of 8d is read as "8 penny".

There is also a definite length for each size designation. Starting with a 4 penny nail, we find its length to be 1-1/2 inches. Each nail size greater has a length which is 1/4 inch greater.

See figure on next page for nail sizes.



4d = 1-1/2"
5d = 1-3/4"
6d = 2"
7d = 2-1/4"
8d = 2-1/2"
9d = 2-3/4"
10d = 3"
12d = 3-1/4"
16d = 3-1/2"

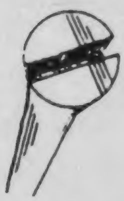
Nail Sizes.

SCREWS

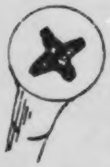
The use of screws, rather than nails, is determined by several factors. These factors may include the type of material to be fastened, a need for greater holding power than nails can provide or the desired appearance of the finished product. Some of the advantages of screws are that they provide more holding power and can be easily tightened to draw the items being fastened securely together, are neater in appearance, and may be withdrawn without damaging the material.

SCREW PARTS

The various parts of a screw are illustrated on the next page. The root diameter is the diameter of the threaded portion, the body is the smooth portion, and the length is that which runs from the tip to the head of the screw.



Slotted head



Phillips head

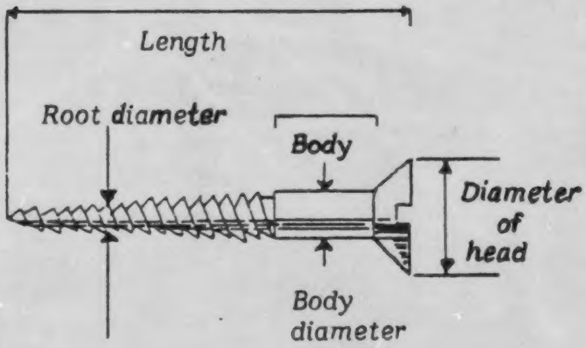
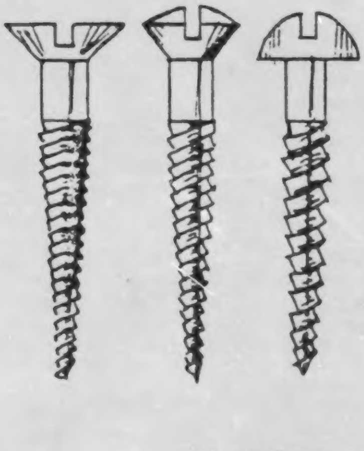


Diagram of a Screw.

SCREW TYPES

Wood Screws

The common wood screw is usually made of unhardened steel, stainless steel, aluminum, or brass. Wood screws are threaded approximately 2/3 of the length of the screw, and have a slotted head designed to be driven by a screwdriver. Wood screws are designated according to head style. The most common types are the flathead, ovalhead, and the roundhead with either a slotted or phillips head. The use of the wood screw is restricted to fastening wood to wood items.



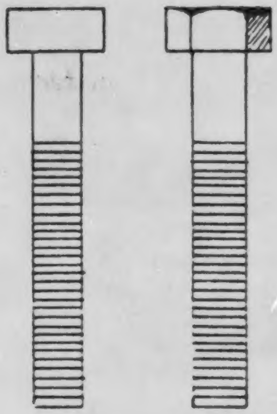
Wood Screws.

Here is a list of common screw sizes:

No. 2	¼ to ½ inch
No. 3	¼ to ⅝ inch
No. 4	⅜ to ¾ inch
No. 5	⅜ to ¾ inch
No. 6	⅜ to 1½ inches
No. 7	[illegible] to 1½ inches
No. 8	½ to 2 inches
No. 9	[illegible] to 2¼ inches
No. 10	⅝ to 2¼ inches
No. 12	⅞ to 2½ inches
No. 14	1 to 2¾ inches
No. 16	1¼ to 3 inches
No. 18	1½ to 4 inches
No. 20	1¾ to 4 inches
No. 24	3½ to 4 inches

Lag Screws

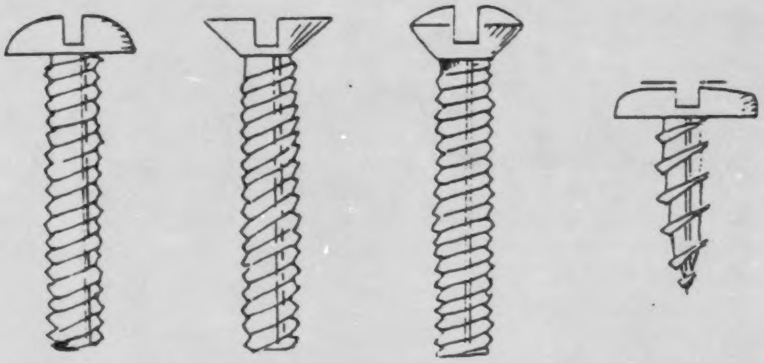
Lag screws are often required in construction. They are longer and much heavier than the common wood screw and have coarser threads which extend more than half the length of the screw. These screws are used to secure metal to wood, wood to wood, wood to concrete, and metal to concrete.



Lag Screws.

Sheet Metal Screws

Sheet metal screws are used for assembling metal parts, light metal to wood, and wood to wood. These screws are made in either steel or galvanized material, and are available with several types of heads: flat, round, oval, and fillister. The sheet metal screws usually have a self-tapping point for easy starting.



Metal Screws.

Sizes of Screws

Wood screws come in sizes which vary from 1/4 inch to 6 inches. Screws up to 1 inch in length increase by eighths, **screws** from 1 to 3 inches increase by quarters, and screws from 3 to 6 inches increase by half-inches. Screws vary in length and size of shaft.

Proper nomenclature of a screw includes the type, material, finish, length, and screw size number.

Length (in.)	Size Numbers																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24	26	28	30
1/4	x	x	x	x																					
3/8	x	x	x	x	x	x	x	x	x	x															
1/2		x	x	x	x	x	x	x	x	x	x	x	x												
5/8		x	x	x	x	x	x	x	x	x	x	x	x	x	x										
3/4			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
7/8			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
1				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
1 1/4.........					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1 1/2.........					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1 3/4.........						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
2						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
2 1/4.........						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
2 1/2.........						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
2 3/4.........							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
3							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
3 1/2.........									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
4									x	x	x	x	x		x		x	x	x	x	x	x	x	x	
4 1/2.........													x		x		x		x	x	x	x	x	x	x
5													x		x		x		x	x	x	x	x	x	x
6															x		x		x	x	x	x	x	x	x

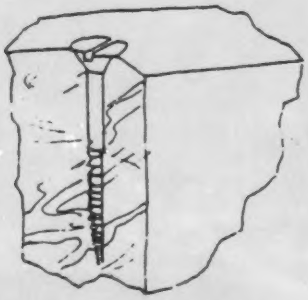
Screw Sizes.

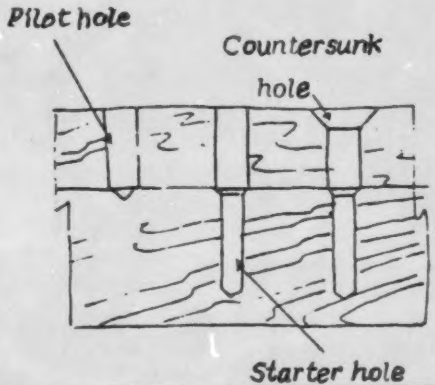
SCREW INSTALLATION

To prepare wood for installing screws, a pilot hole which is the size of the screw diameter must be bored. Then a smaller, starter hole which will anchor the screw threads must be bored. The starter hole is drilled with a diameter less than that of the screw threads, and to a depth 1/2 or 2/3 the length of the threads to be anchored.

Boring holes assures accuracy in the placement of screws, reduces the possibility of splitting the wood, and reduces the time and effort required to drive the screw.

The slotted and phillips flathead and ovalhead screws are countersunk sufficiently to permit a covering material to be used to cover the head.





BOLTS

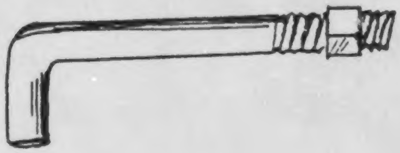
BOLT TYPES

There are five types of bolts used most frequently in heavy construction. They are: anchor, dead head, stove, carriage, and machine bolt.

Anchor Bolt

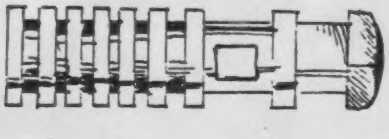
Anchor bolts are by far the most utilized bolts. They come in various sizes and are shaped like an "L". They are made of black metal and in many casses have a galvanized finish for special protection from rust and corrosion.

Anchor bolts are set in concrete in a manner that secures pumps, vessels, and structural beams to their foundations.



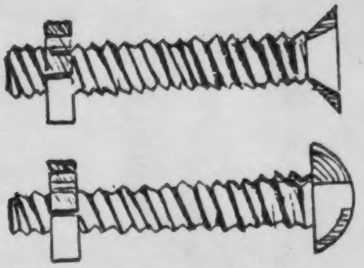
Dead Head Bolt

Dead head bolts are usually made of black metal and are used to secure metal to concrete. A hole is drilled into the concrete and then the bolt is placed into the hole. A light tap with a hammer is required but care must be taken so as not to damage the threads. As the bolt is screwed down into the concrete, it expands the dead head against the wall of the hole and holds firmly.



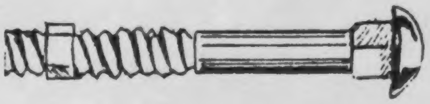
Stove Bolt

Stove bolts usually come in black metal and are used to secure light metal together.



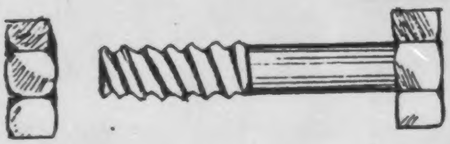
Carriage Bolt

Carriage bolts are either galvanized or come in black metal. They are used to secure wood to wood or wood to metal.



Machine Bolt

Machine bolts are either galvanized or come in black metal. They are used to secure metal to metal, metal to wood, and wood to wood.



BOLT SIZES

Bolts come in a variety of lengths, as well as diameter sizes. They range from a 1/4 inch to a 1 inch diameter. The job to be performed by a specific type of bolt will determine the size to be used.

In critical areas of construction, the sizes and types of bolts are given on blueprint drawings.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

WELDING

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

WELDING

OXYACETYLENE PROCESSES

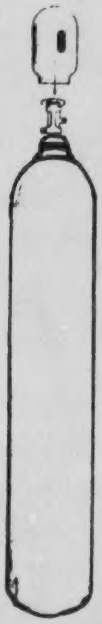
Oxyacetylene welding is based on the principle that, when acetylene gas is burned in the proper proportions, with oxygen gas, a flame is produced, which is hot enough to melt and fuse metals. This proportion is approximately 1 part of acetylene to 2-1/2 parts of oxygen. Oxyacetylene flame cutting uses much of the same equipment, but the principle is different. In oxyacetylene cutting a stream of oxygen is directed against a piece of ferrous metal (metal which contains iron is called ferrous), which has been heated to a red heat. This causes the metal to burn.

Oxygen Cylinder

The oxygen cylinder is usually green or yellow in color, so that it can be identified. It is made from a single plate of high grade steel, which has been heat treated to develop toughness and strength. When fully charged, the oxygen bottle, as it is sometimes called, contains 244 cubic feet of oxygen at a pressure of 2,200 pounds per square inch at 70^{o} Fahrenheit. This oxygen is 99.99% pure and is colorless, odorless and tasteless. Oxygen by itself will not burn, but it does support combustion.

CAUTION: Because of the extremely high pressure at which oxygen is stored in the cylinder, several precautions must be observed at all times.

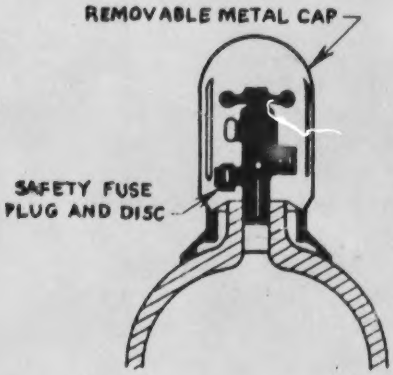
- All cylinders must have Interstate Commerce Commission markings indicating the dates of bottle pressure tests.
- Cylinders must be stored so they cannot be knocked down.
- They should not be stored in an area where extreme temperature changes occur.
- Oxygen cylinders must not be stored near grease, oil or electrical connections. Bringing oxygen into contact with oil or grease may cause a violent explosion.
- They must never be moved without the cylinder cap in place, on top of the cylinder.
- Cylinders which are defective in any way should be taken out of service and reported to the supplier.



Oxygen
Cylinder

Valve Protection Cap

The valve protection cap, or bottle cap, screws onto the cylinder and completely covers the valve. It protects the valve from damage when the cylinder is being moved or if it is accidently knocked over.

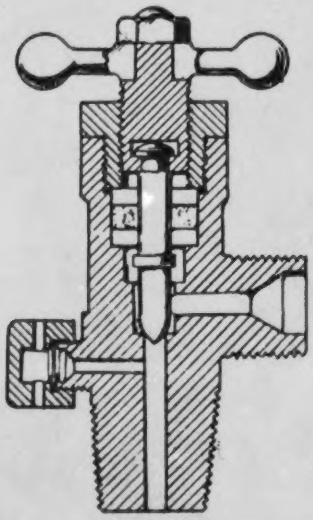


Oxygen Cylinder Cap and Safety Plug

Oxygen Cylinder Valve

The oxygen cylinder valve is attached to the top of the oxygen cylinder. It is used to turn the flow of oxygen on or off, as needed. These valves are double seated. This means that when the valve is completely closed, the flow of oxygen from the cylinder is shut off, and when the valve is opened all the way, the valve seats and prevents leakage of oxygen around the valve stem. The valve should be opened completely when the cylinder is in use.

A safety fuse plug and disc are installed in the oxygen cylinder valve. As the temperature of the oxygen in the cylinder increases, the pressure also increases. If the pressure of the gas in the bottle becomes too great, the safety plug and disc will release the pressure.



Oxygen Cylinder Valve

Acetylene Cylinder

The pressure in acetylene cylinders is not as high as that in oxygen cylinders. For this reason, acetylene cylinders are rolled to the size needed and welded at the seams.

Acetylene cylinders are filled with a porous material, such as fuller's earth or balsa wood. A liquid chemical (acetone) is poured into the bottle and is absorbed by the porous material. Acetone absorbs acetylene gas.

Acetylene gas, which is made by mixing water and calcium carbide (a gray, rock-like substance), has a strong disagreeable odor, resembling garlic. It is highly inflammable and, in combination with oxygen, produces the hottest flame known (5,800° - 6,300° Fahrenheit). When there is not enough oxygen present it burns with a smoky, yellow flame.

CAUTION: Because acetylene gas is highly inflammable and explosive, certain safety precautions must be observed.

- Cylinders must be tested and certified by the Interstate Commerce Commission.
- Cylinders which leak or are defective in any way should be taken out of service and reported to the supplier.
- Free acetylene gas (that which is not absorbed in acetone) must not be stored at pressures above 15 pounds per square inch. Above this pressure acetylene becomes very unstable and may explode.
- If large numbers of acetylene cylinders are stored close to oxygen cylinders a fire resistant wall must be built between the two types of cylinders.
- Cylinders should never be used in any position but the upright position. Liquid acetone can run into the gages and hoses if the cylinder valve is opened while the cylinder is lying on its side.
- Never store acetylene cylinders where excessive heat may contact them.

Acetylene Cylinder

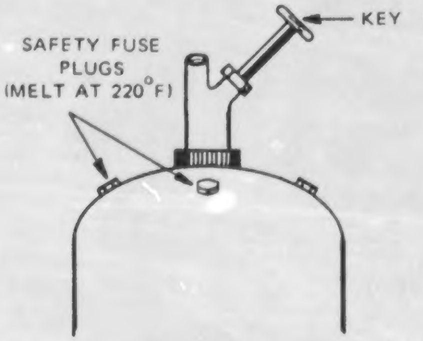
Acetylene Cylinder Valves

The acetylene cylinder valve is attached to the top of the acetylene cylinder. It is used to turn the flow of acetylene on or off as needed. Acetylene cylinder valves are not double seated, because they do not have to withstand the high pressure that oxygen cylinders do.

These valves are of two types. One type has a handwheel, resembling that on the oxygen cylinder valve. The other has a square stem, without the wheel, and is turned on and off with a special wrench, called a key.

CAUTION: The acetylene cylinder valve should never be opened more than 1 1/2 turns. In this way, it can be turned off quickly in case of fire. For the same reason, the key should always be left on the valve.

Acetylene cylinders have plugs installed in them for safety. These plugs are made of a metal which melts at a low temperature. Any excessive heat, which would cause the gas in the cylinder to reach higher pressure, melts the plugs. This allows the acetylene to escape and prevents an explosion.



Acetylene Bottle Key and Fuse Plugs

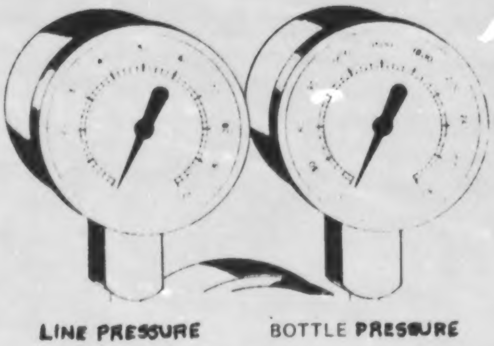
Oxygen Regulators

Full oxygen cylinder pressure is 2,200 pounds per square inch. It is impossible to weld with this much pressure, so a regulator is installed on the cylinder. This regulator allows the welder to set the pressure at reduced amounts. It has a safety device, which vents the pressure if it exceeds safe limits.

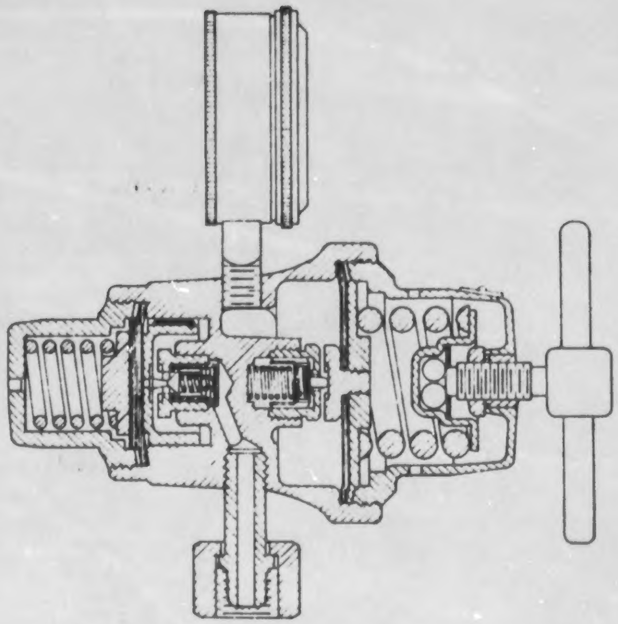
Regulators are equipped with two gauges. One indicates the cylinder pressure, while the other indicates the working or torch pressure.

The regulator is equipped with a nut, which screws onto the cylinder valve. The threads are conventional, right-hand threads. To install the regulator, tighten the nut with the wrench supplied by the manufacturer or with an adjustable wrench. Use no oil on this connection.

(Illustrations on next page).



Oxygen Gauges



Oxygen Regulator

Acetylene Regulators

Acetylene regulators are similar to oxygen regulators, with two exceptions. All acetylene fittings have left-hand threads. This is important to remember, as the fittings may be damaged by attempting to turn them the wrong way. The reason for the left-hand threads on acetylene fittings, is to prevent them from being accidentally installed on oxygen equipment.

The second way in which they are different from oxygen regulators is that acetylene gauges have lower numbers than oxygen gauges. As a general rule, the acetylene cylinder pressure gauge registers to 500 pounds per square inch. The acetylene working pressure gauge registers to a maximum of 15 pounds per square inch. Also, the numbers and graduations on the dial of oxygen gauges are normally green, while on acetylene gauges they are normally red.

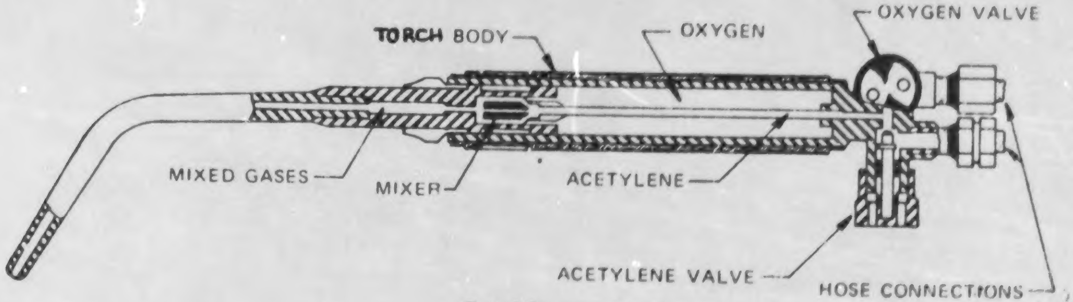
NOTE: Gauges are delicate mechanisms and through mishandling they may not register correctly. However, the regulator will hold the correct pressure, even if the gauge does not indicate it correctly.

Torch

The welding torch (or blowpipe) has separate inlets for oxygen and acetylene. It transports the gases to the mixing chamber where they mix in the correct proportion for welding. The mixing is controlled by two valves on the handle, each of which may be opened and closed to regulate the flow of gases for the welding flame.

The most commonly used torch is the equal pressure (or medium pressure) type. In this type approximately equal amounts of oxygen and acetylene are used for welding.

As with all other oxyacetylene equipment the torch has left-hand threads on the **acetylene** connection and right-hand threads on the oxygen connection.



Equal Pressure Torch

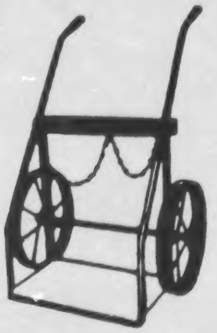
Welding Tip

Different sized tips must be attached to the torch. These tips have a mixing chamber and orifices (holes) to supply different flame sizes. The tip concentrates the gases coming from the torch so that the flame can be directed toward the weld to be made.

Tips come with different size orifices, to vary the size of the flame. When a tip with larger holes is used more gas can escape. This provides a larger flame for welding on heavier metal, where more heat is required. Tips should be kept clean and in good working order.

Bottle Cart

A bottle cart is a two-wheeled cart equipped with a chain for fastening the cylinders securely. When oxyacetylene welding equipment is installed on the bottle cart, it makes a portable welding station whiich can be wheeled to the job.

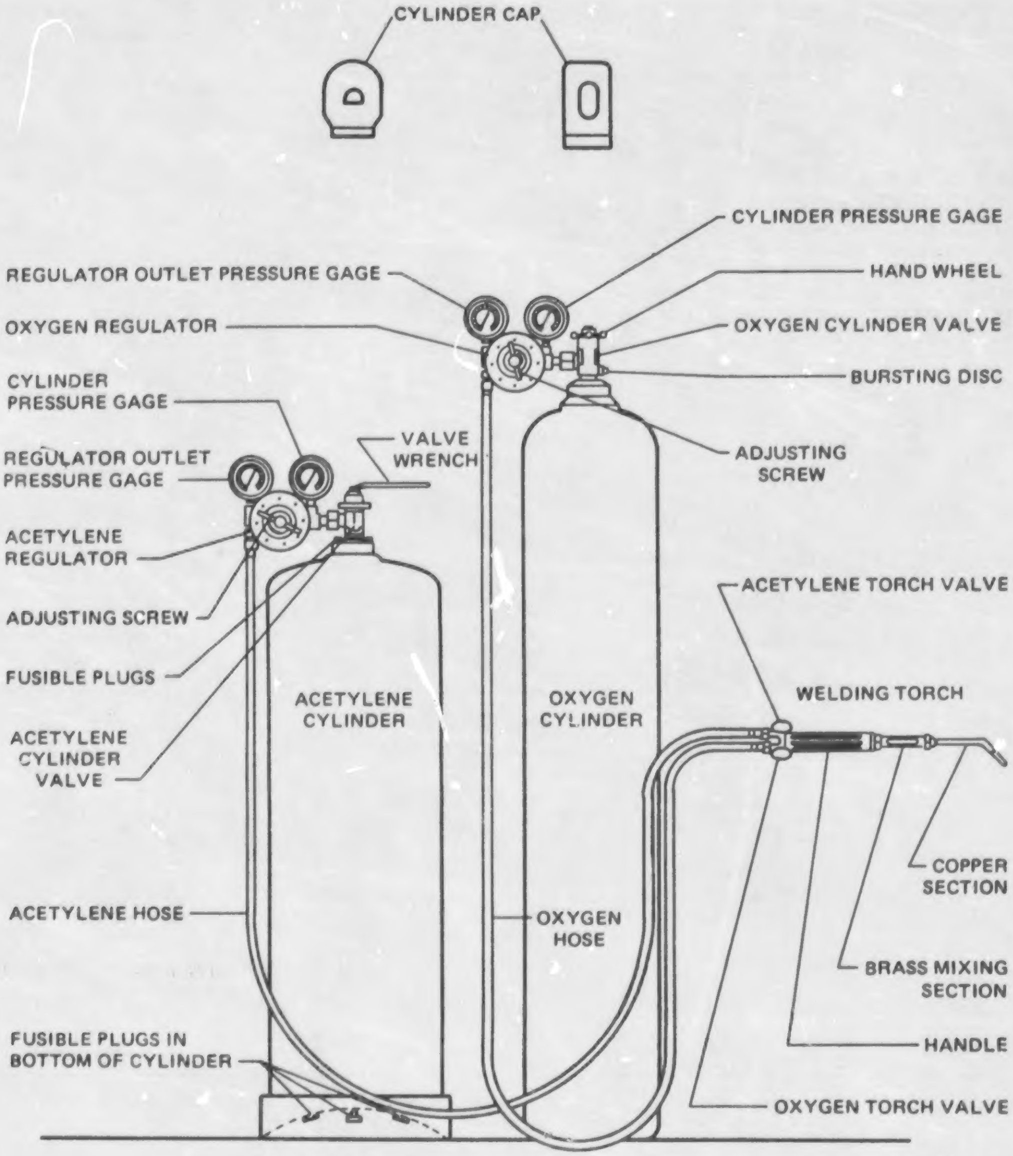


Bottle Cart

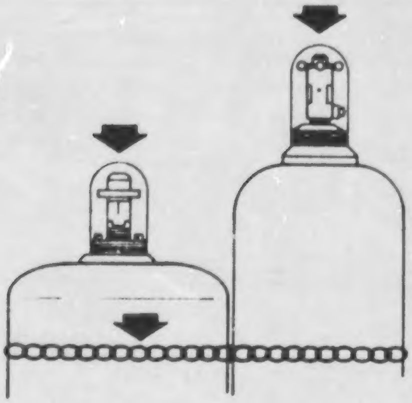
Hoses

Special hoses are used for oxyacetylene welding equipment. They are made to withstand the high welding pressures. Welding hoses are supplied in 3/16", 1/4", 3/8" and 1/2" sizes. Select the correct size for the equipment to be used. They may be furnished as a double hose, connected by a rubber web and molded together. If single hoses are used, tape them together at 18 inch intervals to keep the unit solid.

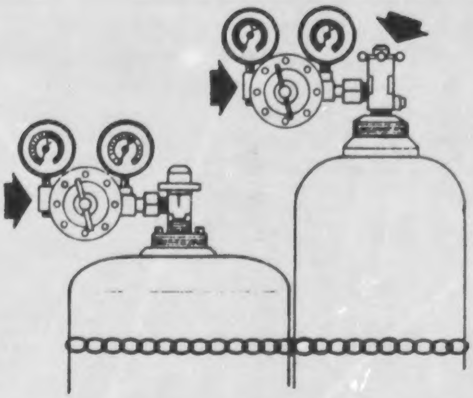
Oxygen hoaes are green in color and have right-hand threads. Acetylene hoses are red in color and have left-hand threads. Also, acetylene hose fittings have grooves cut into the nuts, to indicate a left-hand threaded connection.


CYLINDER CAP
CYLINDER PRESSURE GAGE
REGULATOR OUTLET PRESSURE GAGE
HAND WHEEL
OXYGEN REGULATOR
OXYGEN CYLINDER VALVE
BURSTING DISC
CYLINDER PRESSURE GAGE
VALVE WRENCH
REGULATOR OUTLET PRESSURE GAGE
ADJUSTING SCREW
ACETYLENE REGULATOR
ADJUSTING SCREW
ACETYLENE TORCH VALVE
FUSIBLE PLUGS
WELDING TORCH
ACETYLENE CYLINDER
OXYGEN CYLINDER
ACETYLENE CYLINDER VALVE
COPPER SECTION
ACETYLENE HOSE
OXYGEN HOSE
BRASS MIXING SECTION
FUSIBLE PLUGS IN BOTTOM OF CYLINDER
HANDLE
OXYGEN TORCH VALVE

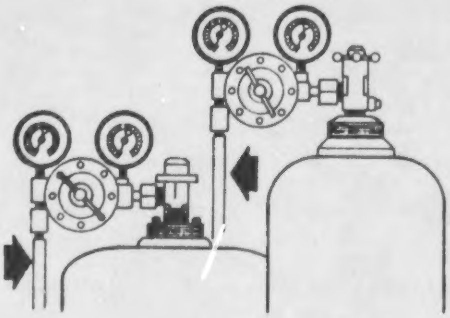
Steps in Assembling the Oxyacetylene Rig.



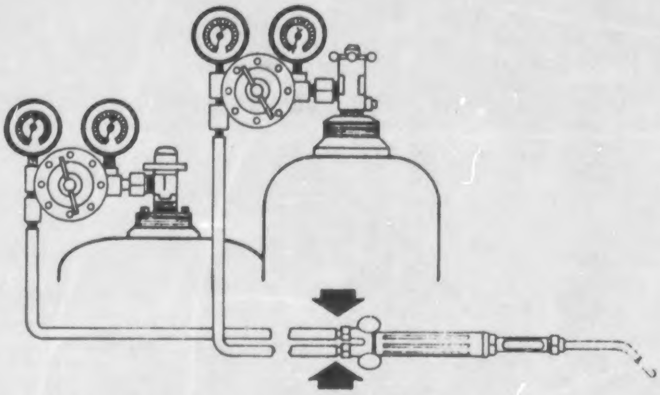
1. TWO BOTTLES SAFETY CHAINED AND CAPS IN PLACE



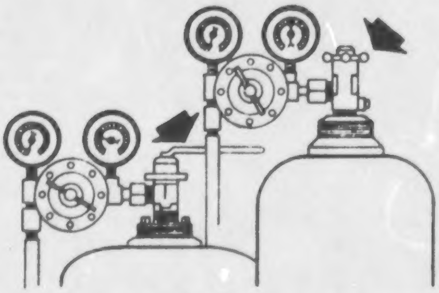
2. CRACK VALVES – INSTALL REGULATORS



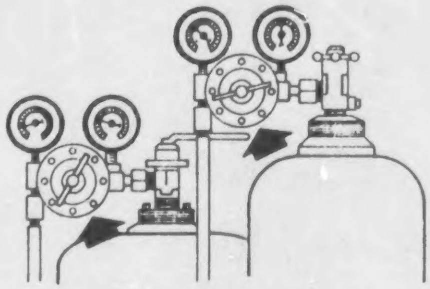
3. INSTALL HOSES.



4. INSTALL TORCH.



5. OPEN BOTTLE VALVES.



6. SET ADJUSTING SCREWS FOR LINE PRESSURE.

LIGHTING THE OXYACETYLENE TORCH

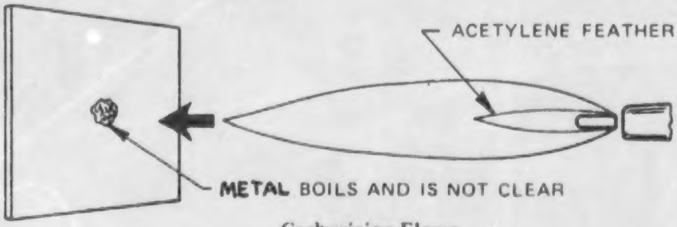
Flames

Three basic flames can be made by adjusting the valves on the welding torch.

- The carburizing flame
- The neutral flame
- The oxidizing flame

Carburizing Flame

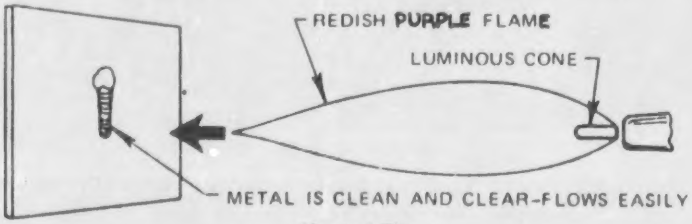
A carburizing flame is the result of too much acetylene gas in the flame. This flame may be recognized by a long streamer of green colored gas which burns around the inner cone of the flame. This is called an acetylene feather. A carburizing flame is used to make the outside of metal hard, but is not good for a weld. The addition of the extra acetylene to the melted weld adds carbon to the metal and makes a hard, brittle weld. When this flame is used on melted parent metal, it causes the puddle to turn dark red and gives it a boiling action.



Carburizing Flame

Neutral Flame

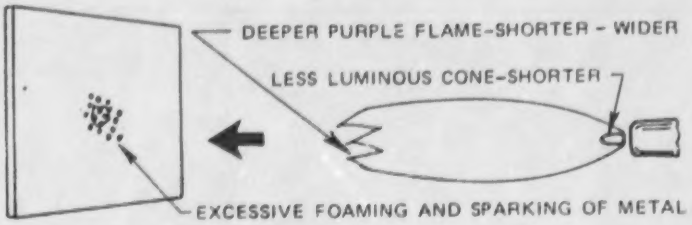
The neutral flame is the welding flame. This flame can be recognized by a sharp inner cone and the absence of an acetylene feather. It is made up of 2 1/2 parts of oxygen and 1 part of acetylene. One part of the oxygen in the flame and one part of the acetylene come from the bottles. The other 1 1/2 parts of oxygen are picked up from the air around the welding tip. A neutral flame does not add anything to or subtract anything from the parent metal (the metal being welded). The acetylene torch is adjusted for a neutral flame, for most welding jobs that require the metal to be melted and mixed together.



Neutral Flame

Oxidizing Flame

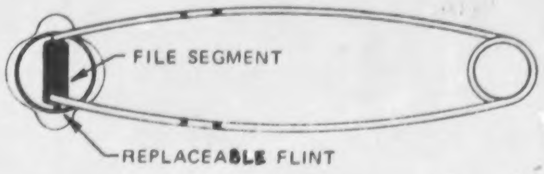
An oxidizing flame is the result of having too much oxygen in the gas mixture. This flame can be identified by a shorter inner cone and a whistling sound. It causes the molten metal to boil and spark. The additional oxygen in the flame causes the metal to burn, resulting in a brittle weld. A slightly oxidizing flame may be used for brazing, but it is not used for fusion welding.


DEEPER PURPLE FLAME-SHORTER - WIDER
LESS LUMINOUS CONE-SHORTER
EXCESSIVE FOAMING AND SPARKING OF METAL

Oxidizing Flame

Striker

The striker produces a spark by dragging a piece of flint across a file. A striker must always be used to light the oxyacetylene torch. The use of matches creates a hazard and may result in personal injury. The flints in most strikers may be replaced when the original one is worn out.


FILE SEGMENT
REPLACEABLE FLINT

Striker

Goggles

Goggles are to be worn when welding. They are made in many shapes and sizes, to suit the infividual welder. Welding goggles have dark lenses which filter out ultraviolent and infrared rays. For oxyacetylene welding they should be equipped with #4 or #5 filter lenses, either blue or brown.

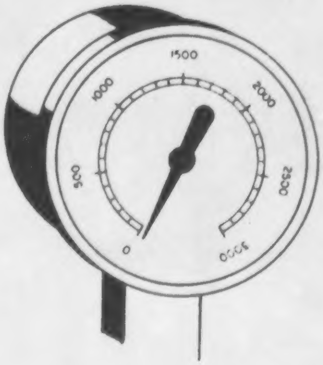
LIGHTING THE OXYACETYLENE TORCH

Procedure

1. Set up the welding equipment, following the procedures outlined.

2. Install the tip on the torch body.

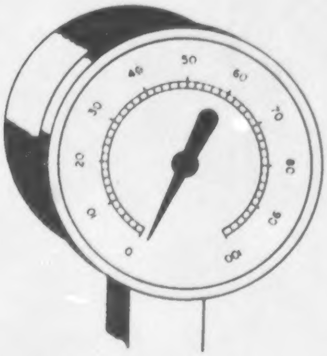
3. Open the oxygen cylinder valve slightly until pressure registers on the high pressure gauge then open the valve fully.



High Pressure Gauge (Oxygen)

4. Turn the adjusting screw on the regulator to the right until pressure registers on the low pressure gauge.

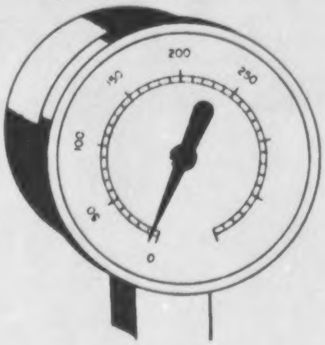
Set the oxygen pressure at about 5 psi.



Low Pressure Gauge (Oxygen)

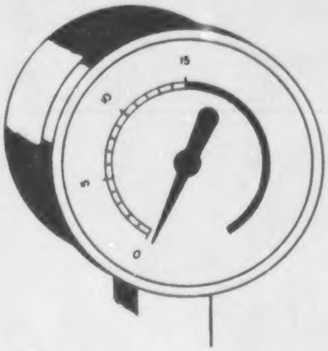
5. Open the oxygen needle valve on the torch handle and readjust the regulator until about 5 pounds registers, with the needle valve open. Close the needle valve.

6. Open the acetylene cylinder valve slightly until pressure registers on the high pressure gauge, then open it 1/2 turn.



High Pressure Gauge (Acetylene)

7. Turn the adjusting screw to the right until pressure registers on the low pressure gauge.



Low Pressure Gauge (Acetylene)
(Note Calibration Stops at 15 lbs.)

8. Open the acetylene needle valve on the torch handle and readjust the screw on the regulator until about 5 pounds registers, with the needle valve open. Close the needle valve on the torch.

9. Open the acetylene needle valve on the torch about 1/2 turn. Hold the striker in the left hand (if right-handed), the torch in right hand, and strike a spark in front of the escaping gas.

10. Open the needle valve on the torch until the flame jumps away from tip about 1/8". The flame will appear turbulent, but will not smoke.

11. Open the oxygen needle valve on the torch slowly, adding oxygen to the burning acetylene.

12. As oxygen is added to the acetylene, observe the luminous cone at the tip, and the long greenish-color envelope around it. The green envelope is the excess acetylene of the carburizing flame.

13. Continue to add oxygen by opening the oxygen needle valve until the feather of acetylene just disappears. The inner cone will now appear soft and luminous. This is a neutral flame.

14. If more oxygen is added now, the flame becomes pointed and white in color. In addition, it makes a sharp whistling sound. This is an oxidizing flame.

15. Practice adjusting the torch to carburizing, neutral, and oxidizing flames.

16. Shut off the acetylene needle valve on the torch; shut off the oxygen needle valve on the torch; shut off both cylinder valves completely; open the needle valves on the torch handle and drain the hoses. (Watch the gauges until they register 0.)

17. Close the needle valves on the torch, release the pressure adjusting screws on the regulators by turning the handles to the left; coil the hoses and hang them up on the hose holder.

OXYACETYLENE WELDING HINTS

A. An oxacetylene weld should always have 100% penetration. This means that the weld appears on the bottom of the parent metal as well as on the top. Poor penetration causes the metal to break in the weld. However, too much penetration causes the molten metal to drip through and hand down below the parent metal.

B. Right-handed welders usually hold the torch in the right hand and weld from right to left, adding the filler rod at the front of the flame. This procedure is called forehand welding. Left-handed operators weld from left to right, but the rod is still added at the front of the flame, since the torch is held in the left hand and the filler rod in the right.

C. Flat welding is the most desirable position for welding, since the welder can control penetration and bead appearance easily.

D. Filler rod is commonly called welding rod. It is added to the molten puddle to build up the cross section of weld where the penetration has forced the molten metal below the surface of the parent metal. To insure good penetration, filler rod should be added only after the puddle has been formed. The weld should have a cross section thicker than the original parent metal, so that strength is added at the point of the weld.

E. A neutral flame is used for welding. On an equal pressure torch, the gauges should be set at approximately the same pressure, if the welding is not to be done in a confined area. Welding in a restricted area, such as a corner of the metal, uses up the atmospheric oxygen rapidly and changes the character of the flame from neutral to carburizing. More oxygen pressure may be needed for such a welding condition.

F. Instructions and demonstration for making the many types of oxyacetylene weld beads and joints should come from your instructor.

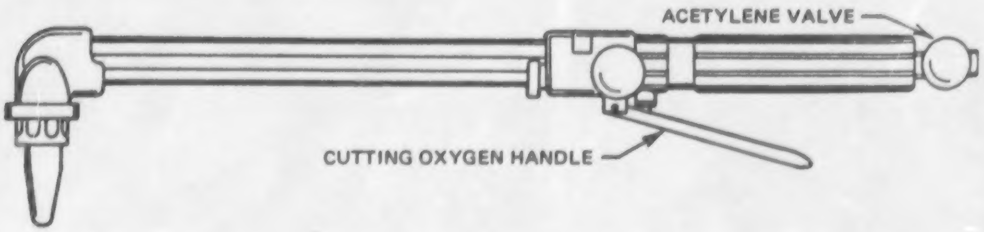
OXYACETYLENE CUTTING

Oxyacetylene cutting is done by directing a stream of oxygen onto the ferrous metal, which has been preheated. The oxygen burns the metal. By controlling the amount of preheat and the size of the stream of oxygen, a cut may be made with clean, smooth sides. The cut is called a kerf.

Oxyacetylene cutting is one of the most used oxyacetylene processes. The cutting torch can be used to cut intricate shapes or to make straight, clean cuts. The cutting, or burning, process does not change the chemical composition of the metal. Therefore, any ferrous metal can be welded immediately after it has been cut. However, slag (oxidized metal) is sometimes left at the bottom edge of the cut. This must be removed by grinding or chiseling. If oxidized metal is included in the puddle it will contaminate the weld. Metal should always be clean before welding.

Cutting Torch

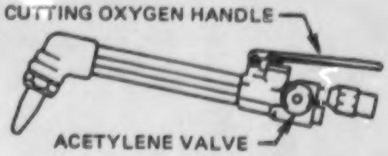
The cutting torch is designed only for cutting ferrous metals. To install the cutting torch the welding torch handle must be removed from the hoses. The cutting torch is then installed in its place. The cutting torch is designed for heavy cutting and performs better over long periods of time than the cutting head.



Cutting Torch

Cutting Head

The cutting head is an attachment to the welding torch. By removing the tip from the welding torch, the cutting head may be screwed onto the torch handle. In this manner, a welding torch may be used for cutting.



Cutting Head

Oxygen Pressure

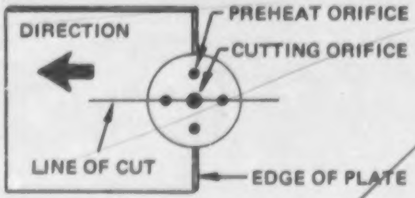
Since large amounts of oxygen are required to burn the metal, more oxygen pressure is needed for cutting than for welding. When using a cutting torch, or cutting head, the gas pressures should be regulated according to the manufacturer's specifications for the torch being used.

Cutting Tip

The cutting tip is designed especially for cutting and cannot be used for welding. Cutting tips are made with a hole in the center, through which the stream of oxygen is directed at the cut. A group of holes around the center hole give off a neutral flame which preheats the metal. Depending on the size of the tip, there are 4, 6, 8 or 12 preheat holes. Each of these is like a miniature welding tip and when the torch is lighted, it should be adjusted so that each of the preheat holes makes a neutral flame.

When the metal to be cut has been preheated to red-hot, the cutting oxygen valve is pressed. The stream of oxygen will burn (cut) the metal as long as the preheat is maintained. Oxyacetylene cutting must be done at a slow, even rate of speed. If the cut is made too rapidly, the metal may cool down and the cutting action will stop. If this happens the torch should be moved back into the kerf and the metal preheated again. The cut may then be started again.

Cutting Tip



Four-Hole Cutting Tip, Installed for Straight-Line Cut. Make Cut Right to Left

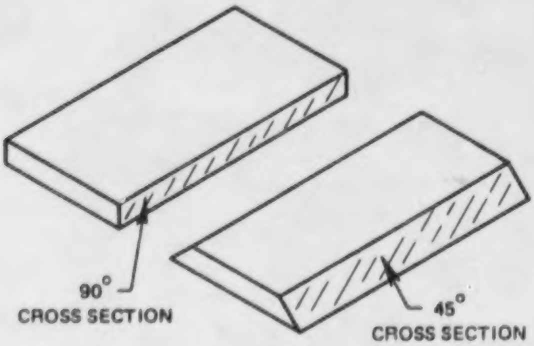
BEVELING PLATE WITH THE OXYACETYLENE CUTTING TORCH

Ordinarily, 100% penetration is required of an oxyacetylene weld in order to insure strength in the welded joint. Metal which is over 1/8 inch thick is very difficult to melt through, so some method has to be provided to insure complete penetration. Metal 1/8 inch to 3/16 inch thick is frequently gapped for welding, but the edge of metal over 3/16 inch thick should be beveled. This is done by cutting the edge of the metal on an angle.

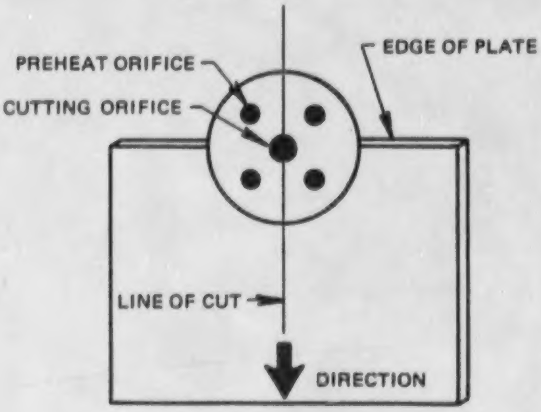
Cutting straight through a piece of steel leaves a cross section the same width as the thickness of the original metal. However, when the edge is beveled, the cross section is increased.

Beveling leaves the bottom of the plate with a very thin edge, which has a tendency to melt off during welding. This edge is generally ground square to a thickness of 1/16 inch, to prevent the edge from melting off. This ground shoulder is called a land.

Sometimes when bevels are made, a small increase of oxygen pressure is necessary to cut the larger cross section of the bevel. To cut a bevel, the cutting tip should be turned so the holes line up.



Cross Section of Straight and Beveled Edges

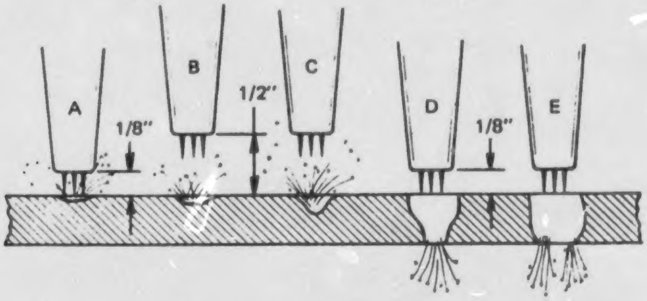


Cutting Tip Installed for Bevel Cut

CUTTING HOLES WITH THE OXYACETYLENE CUTTING TORCH

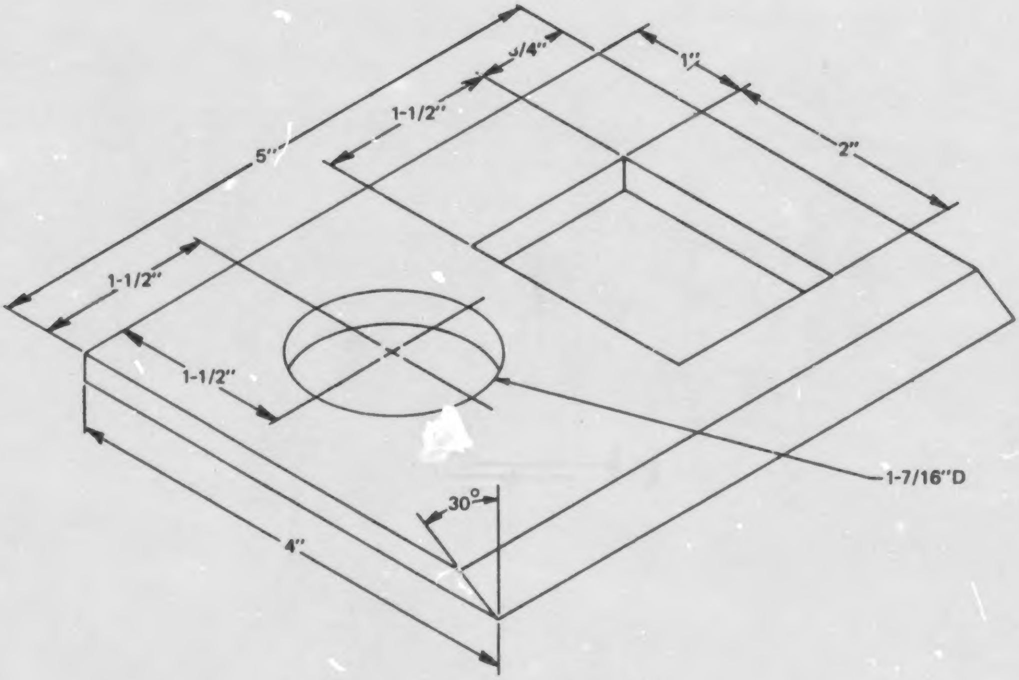
The oxyacetylene cutting torch is a good tool for cutting holes in steel, where a precision fit is not necessary. Round, square, rectangular, and odd-shaped holes can be cut equally well.

As the cutting oxygen valve is opened, after the metal has been preheated to a red heat, the torch tip must be moved upward away from the cut. This is to keep the slag from blowing up into the tip. When the hole is burned completely through the plate, lower the torch until the preheat flames are about 1/8 inch from the surface of the metal. With the hole pierced and the torch in position to keep the metal preheated, cut away from the hole to the mark and around the circle. Clean the slag from the underside when the cut is completed.



Torch Handling Sequence for Hole Piercing

Layout Example



SETTING UP ARC WELDING EQUIPMENT

Arc welding uses the heat produced as electricity jumps the gap from one conductor of electricity to another. As the electricity passes through this gap intense and concentrated head (6,500 to 7,000^{o}F) is produced. The two basic types of shielded-arc (stick-arc) welding are those that use AC (alternating current) and those that use DC (direct current) electricity. In the shielded-electrode method of welding an electric arc is produced between the metal to be welded (base metal) and the electrode. This arc melts the electrode metal which is deposited on and fused with the base metal.

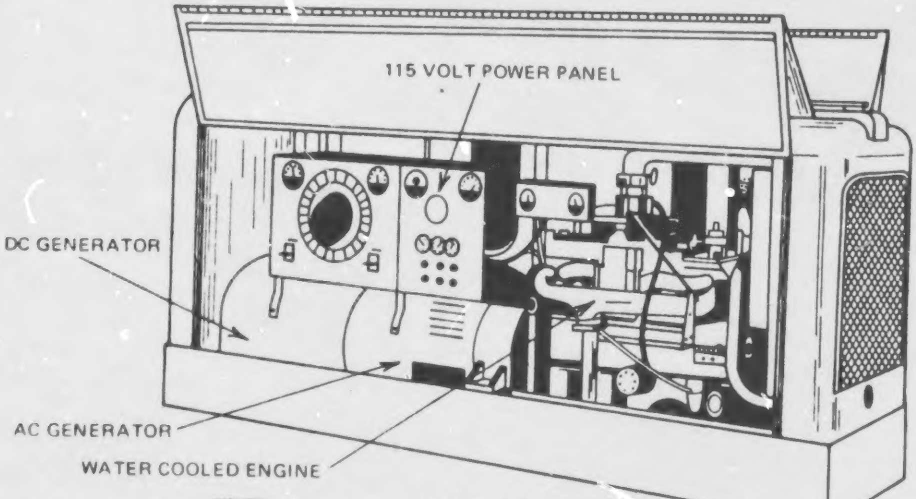
Welding Equipment

The arc welding process uses special equipment. The welding student must set up and operate this equipment according to established industrial standards of safe and economical operation.

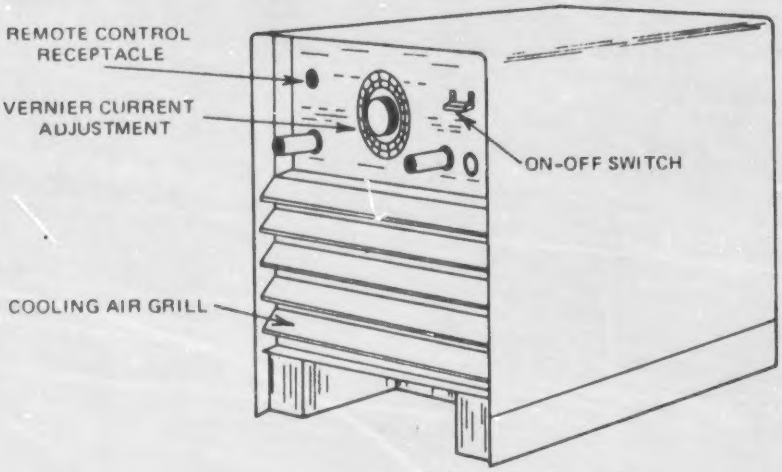
Arc Welding Machine

Arc welding machines are classified as either AC or DC. DC welding machines may be motor driven generators or rectifier welders. A rectifier is a device which converts AC to DC.

Since the DC rectifier welder is most commonly used in shops and in school laboratories, the welding student should concentrate on that type. The DC rectifier furnishes two types of welding current, both of which are utilized for welding and each of which serves specific welding needs in a satisfactory manner.



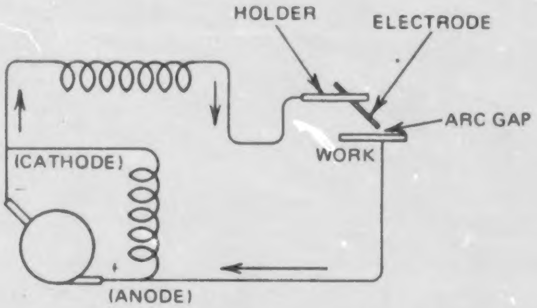
Motor Driven Generator


REMOTE CONTROL RECEPTACLE
VERNIER CURRENT ADJUSTMENT
ON-OFF SWITCH
COOLING AIR GRILL

Rectifier Welder

Direct Current, Straight Polarity (DCSP)

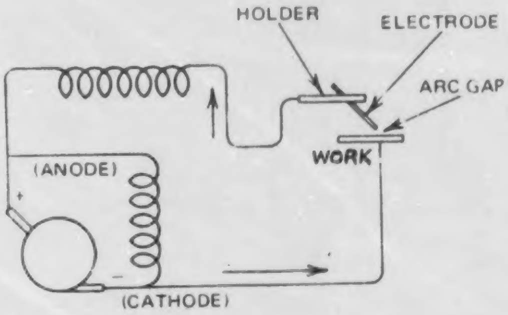
When the parent metal is connected to the positive (+) side of the welder, and the electrode (rod) holder is connected to the negative (-) side of the welder, the circuit is in straight polarity. With the electrode negative the current travels from the electrode to the base metal. DCSP is used with high melting-temperature base metals, for deep penetration, for slow welds and for narrow beads. It is especially recommended for welds which are made in position (on the topside of a horizontal surface).


HOLDER
ELECTRODE
ARC GAP
WORK
(CATHODE)
(ANODE)

Wiring Diagram, DCSP

Direct Current, Reverse Polarity

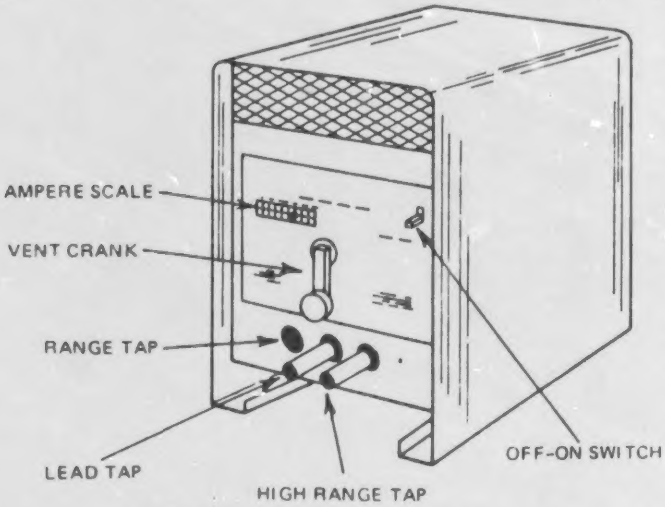
When the parent metal is connected to the negative (-) side of the welder, and the electrode holder is connected to the positive (+) side of the welder, the circuit is called reverse polarity. With the electrode positive the current travels from the base metal to the electrode. DCRP is especially helpful for welding out of position (welds made in any but the flat position), since the parent metal does not heat up as much and has less tendency to run.


HOLDER
ELECTRODE
ARC GAP
WORK
(ANODE)
+
−
(CATHODE)

Wiring Diagram, DCRP

Alternating Current

Most AC welders have transformers which step down the voltage and increase the welding current. Electric current furnished by most electric utilities is 60-cycle, alternating current. (The current reverses its direction of flow 120 times per second.)


AMPERE SCALE
VENT CRANK
RANGE TAP
LEAD TAP
HIGH RANGE TAP
OFF-ON SWITCH

Welding Machine

Welding Electrodes

Most welding electrodes are covered with a coating of flux. This flux forms a gaseous shield which prevents oxygen from contacting the molten metal. The chemical content of the coating varies with the manufacturer's specifications. Welding rods are manufactured and coated to fulfill specific welding functions. The welder must learn to identify electrodes and choose the type most suited for the job at hand.

Electrodes are designated with the letter E, followed by four or five digits - Exxxx(x). The first two (or three) digits indicate the tensile strength of the deposited weld, in thousands of pounds per square inch. For example, in the designation E-60xx, the E indicates that is is an electric welding electrode, and the 60 indicates a tensile strength of 60,000 pounds per square inch. The next digit indicates the position of welding for which the electrode is designed. A 1 in this position indicates an all-purpose electrode, or one which can be used in any position; a 2 indicates that it is for flat or horizontal welding; and a 3 indicates that it is intended for flat position welding only. The last digit refers to the operating characteristics, such as coating and polarity. For example, an E-6011 electrode is made of metal with a tensile strength of 60,000 pounds per square inch (60), for use in any position (1), and either AC or DCRP (1).

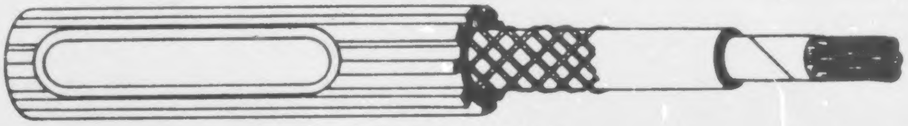
In addition, rods are generally coded with a color on the end or a colored spot or spots on the covering. Some rods are also designated by a group color.

Electrode Classification	End Color	Spot Color	Group Color
E 6010	.....	.....	.....
6011	.....	Blue	.....
6012	.....	White	.....
6013	.....	Brown	.....
6014	Red	Brown	.....
6020	.....	Green	.....
6024	.....	Yellow	.....
7010-A1	Blue	White	.....
7011-A1	Blue	Yellow	.....
7016	Blue	Orange	Green
7018	Black	Orange	Green
7020-A1	Blue	Yellow	Silver
8015-B1	White	Brown	Green
8016-B1	White	Black	Green
9016-B3	Brown	Blue	Green
10013-6	Green	Brown	Silver
10015-6	Red	Red	Green
10016-6	Green	Orange	Green
12016-6	Orange	Orange	Green

Fig. 1-6 Color Coding of Electrodes

Leads

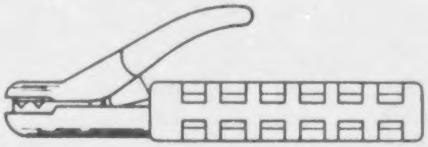
The cables used to carry the electric current to the work and back to the welding machine are called leads. Well-built leads of adequate size to carry the current used are essential. Leads which are used a considerable distance from the welding machine must be larger than leads used for jobs close to the machine. The leads are subjected to much wear and should be of high quality to ensure long service.



Welding Cable

Electrode Holder

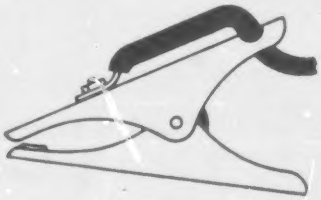
The electrode holder is the part of the arc welding equipment held by the welder. It is attached to the electrode lead on the welding machine. The "stinger", as it is sometimes called, is a well-insulated handle which is made to withstand the heat from welding.



Electrode Holder

Ground Clamp

The ground cable from the machine to the work is generally connected to a spring-loaded clamp which can be easily attached to the work. This is the ground clamp. In order to do a good job of welding, the ground must be solidly connected to the work.

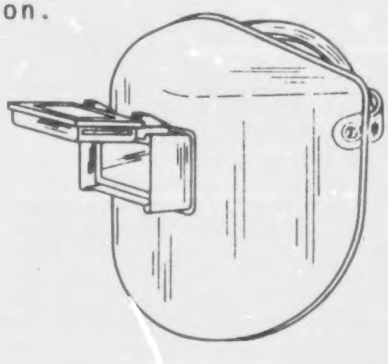


Ground Clamp

Helmet

The helmet is generally made of fiber, and formed to cover the front half of the welder's head. An opening is provided in front of the eyes, and a clear-glass cover lens is installed in the opening. Behind the cover lens is a colored glass which filters the infrared and ultraviolet rays from the arc. The clear-glass lens is provided to catch the spatter from the welding process which would otherwise adhere to the colored lens. (The clear glass lens is much less expensive than the colored lens.)

The welding helmet should be examined frequently to insure that no cracks or holes are present which might allow the arc light to leak through. The cover lens and colored lens must be free of cracks or chips for absolute eye protection.



Additional personal equipment should consist of:

- Cap
- Leather gloves
- Leather jacket
- Safety glasses (flash goggles)
- High shoes or boots
- Other wearing apparel should be of a type which is not readily flammable

Arc Welding Safety

Arc welding is not hazardous if a few fundamental safety rules are obeyed. The following points should be observed in addition to the general arc welding safety rules listed in this unit.

- Radiation from the arc is dangerous to the eyes. The arc gives off infrared and ultraviolet rays which may burn the eyes and the skin. An arc welder's helmet, with a suitable colored lens, must be worn to keep the rays from the skin and eyes.

- Flying sparks and small globules of molten metal are present most of the time when arc welding. Protective clothing which is not highly flammable, gloves, and high shoes help to protect the welder from burns.

- Avoid striking an arc when other persons are close. Warn others that an arc is to be struck so they may protect their eyes from the arc.

- Fumes given off from the arc and the material being welded may be injurious. Adequate ventilation is required at all times when welding is in process.

- Electric shock is always a possibility. Be sure the floor is dry and wear dry gloves. Use an insulated electrode holder.

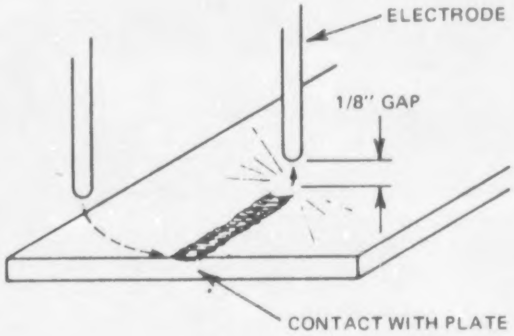
- The danger of burns is always present. Do not handle hot metal with the hands. Use tongs or pliers.

Striking the Arc

When a ground and a wire carrying an electrical charge contact each other, an arc (continuous spark) occurs, causing intense heat and bright light. This is the principle on which arc welding operates, except that after the arc is started, the wlding electrode is moved a short distance away from the parent metal. This keeps a constant arc and continuous heat. An arc length of 1/8 inch is maintained most of the time. Lengthening the arc by moving the electrode farther away from the parent metal increases the heat and the size of the puddle.

Improper arc length can sometimes be determined by visually inspecting a completed weld. Too short an arc can cause poor fusion (fusion is the mixing of the parent metal with the weld metal), undercutting (ar area where metal is missing), and porosity (pinholes). Too long an arc can cause lack of concentration of the heat, excessive splatter, poor penetration (penetration is the depth of the weld in the parent metal), and arc action which is not smooth. Holding the arc too short can also cause the electrode to stick to the parent metal.

The arc may be struck by dragging the electrode across the grounded metal much as a match is struck. If the electrode has a heavy flux coating, it may be necessary to break the coating away from the end of the rod before contact can be made.

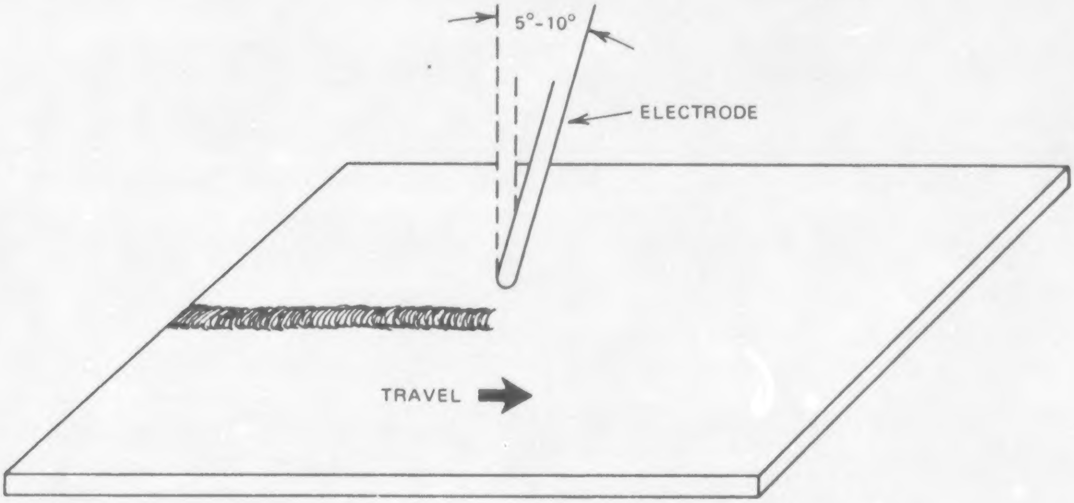


After the arc is established, movement across the plate must be made in a steady forward motion, and the arc must be kept a uniform length. Too rapid progress will result in poor penetration. Right-handed welders generally progress from left to right, so that the weld puddle can be seen and the filling (or buildup) of the rod can be controlled. Left-handed welders should work from right to left.

The heat of the arc melts a crater into the parent metal which must then be filled with the electrode metal. As the electrode is melted into the weld, it is thoroughly mixed with the parent metal. It is not enough to lay a bead on the parent metal. Thorough penetration and fusion between parent metal and electrode metal must take place. As the electrode melts it must be gradually lowered towards the weld to maintain the correct length of the arc.

Electrode

After the arc has been started, the electrode should be held away from the plate to begin the weld. A good rule to follow is to keep the arc at a distance equal to the diameter of the rod being used. The rod must be held perpendiuclar to the plate being welded, and tipped slightly (about 10 degrees) in the direction of travel. The bead width should be approximately twice the diameter of the rod.



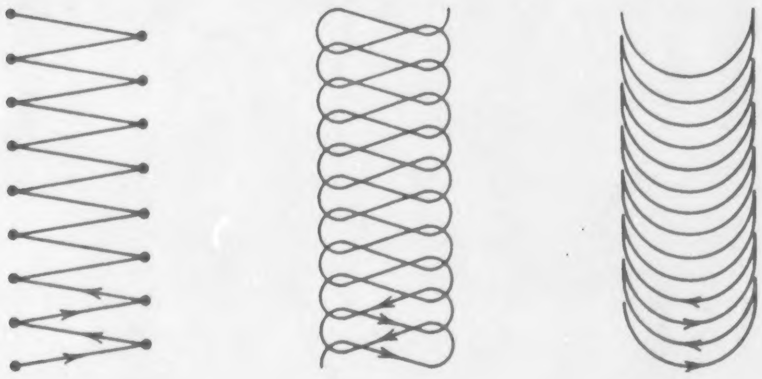
Electrode Angle for Filling Puddle and Welding

Weave Bead

Weaving a bead increases the width of the deposit. It also increases the overlap. Weaving is used to widen a bead, to fill undercut at the sides and to assist in slag formation. Weaving is generally recommended for filling poor fitting joints.

A weave bead is deposited by moving the rod back and forth across the surface to be welded. Stringer beads may be run at the edges first. Several different electrode movements may be used, but weaving is generally done in the flat position using a semicircular motion to the left and the right.

See next page for examples.



STRAIGHT ACROSS FIGURE "8" "U"

Weave Bead Techniques

Flat Position

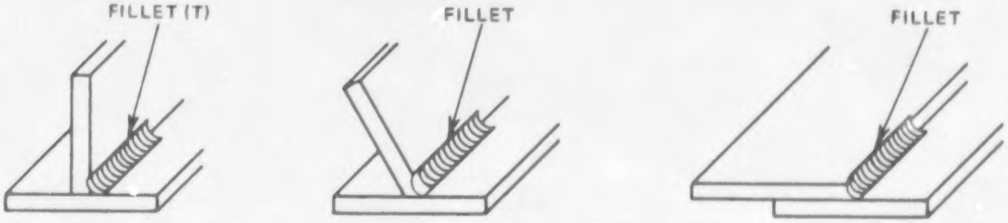
A weld made on the topside of the parent metal and within 30 degrees of horizontal is called a flat weld. The flat position is the most desirable position for welding, since the operator can see the work easily.

REVIEW QUESTIONS

1. Draw a sketch of the motion most frequently used for weaving a bead in the flat position.
2. Should stringer beads or weave beads be used to fill poorly fitting joints?
3. Describe the flat welding position.
4. Why is the flat position considered the most desirable position for welding?
5. What is a positioner?
6. Describe two methods which can be used to keep the sides of a weave bead in a straight line.
7. When one bead runs over the top of another, why is it necessary to clean the slag from the first bead?

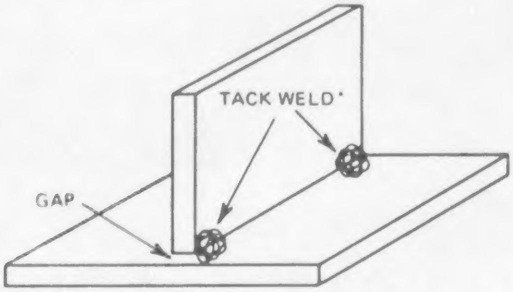
Fillet Weld

The fillet weld is the type of weld used most often in industry. A fillet weld is a weld made on two pieces of metal which are joined in any way other than in a flat plane. A fillet is a reinforcement, and a weld made in an inside corner is called a fillet weld. Fillet welds are sometimes called T welds, when the pieces form a 90-degree angle. However, not all fillet welds are T welds, because the pieces may meet at an angle other than 90 degrees.

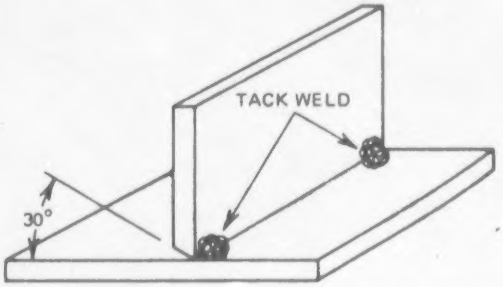


Fillet Welds

When the pieces to be welded are less than 3/16 inch thick, welding on both sides of the joint should produce a strong joint. When thicker metal is welded the joint must be prepared in such a way that the weld penetration is 100 percent. The pieces may be gapped. Another method is to bevel the edge so the weld can penetrate the joint.



Gapping the Pieces for a Fillet Weld



Beveled Edge for a Fillet Weld

Expansion and Contraction

Because metal expands (increases in size) as it is heated and contracts (decreases in size) as it is cooled, allowances must be made for warpage. The metal should be tack welded in position to keep it aligned during the welding. Sometimes the pieces can be tacked in such a way that they are pulled into line by the contraction which takes place as the joint cools. Another method is to clamp the parts in a manner which resists the force of contraction. When neither of these methods can be used, the parts may be welded intermittently on each side (short welds alternately on opposite sides of the joint).

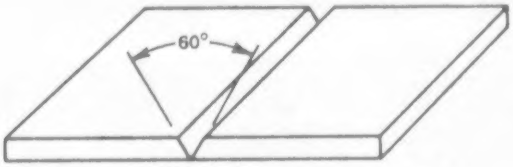
Butt Weld

A butt weld joins the edges of two pieces of metal which are in line with one another. When welded, the two pieces of metal form a flat surface.

For a butt weld to have full strength it must have 100 percent penetration into the parent metal. When 100 percent penetration is achieved, the bottom edges of the plates will be completely fused together. The first pass (or penetration pass) is most important, since failure to join the plates completely can cause a break in the metal or the weld.

Preparation for a Butt Weld

Metal which is over 3/16 inch thick must be prepared so that the first pass of the weld will have complete penetration. The pieces to be welded may be gapped to improve penetration. However, if the pieces are over 3/16 inch thick, the edges will melt rapidly and may fill the gap without completely fusing the bottom edges of the joint. If the parts can be welded from both sides this will improve fusion, but often butt welds must be made where the metal is welded from one side only. Such welds can be prepared by beveling the edges of the two plates with a grinder. Usually the edges are beveled about 30 degrees so that when they are fitted together their edges form a V of about 60 degrees.



Beveling Plate for a Butt Weld

Beveling forms a very thin edge, which would burn away rapidly. To prevent this edge from burning away, a land (flat nose) is ground on the edge. This land should be about 1/16 inch thick.

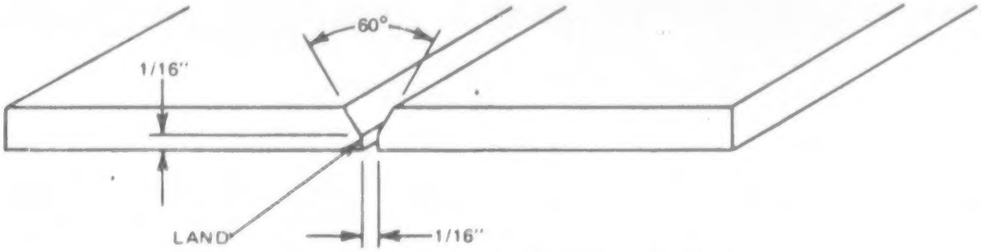


Plate Prepared for a Butt Weld

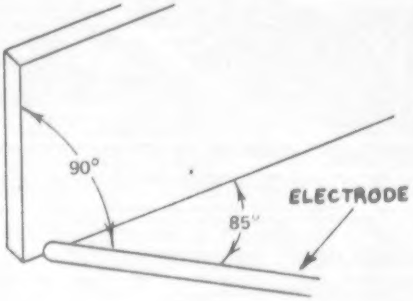
When the plates are tack welded, a narrow gap is left between them. This helps insure 100 percent penetration of the root pass. After each pass, the weld must be chipped and cleaned, to prevent slag from being trapped in the following passes.

Horizontal Weld

An out-of-position weld is a weld made in any position other than flat. A horizontal weld is a weld made in a horizontal line and against a surface which is approximately vertical.

Horizontal welding presents a problem because gravity works against the welder. The molten metal deposited by the arc has a tendency to sag downwards. This sag must be controlled by rod angle and rod manipulation. Also, care must be taken that an undercut does not develop at the top of the bead. Correct polarity and use of the right electrodes assist in making a good weld.

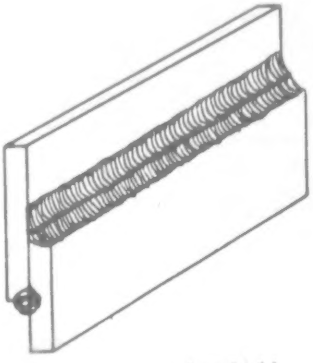
The electrode should be held at an angle of 90 degrees with the plate being welded, then pointed slightly toward the weld.. If the puddle has a tendency to sag, the electrode can be angled upward slightly (about 20 degrees). In this position, the force of the arc will help hold the molten puddle in place until it has cooled enough to support itself. A slight circular movement of the end of the rod may help the beginning welder maintain bead appearance.



Electrode Angle

Lap Joint

Lap welds are a common application of electric arc welding on mild steel. However, this joint has certain disadvantages which must be recognized. Although the metal may be perfectly lapped, one edge over the other, the space between the overlapped edges is a natural place for corrosion to occur. Moisture can condense in the lap, as a result of heating and cooling. This moisture causes rusting which eventually results in failure of the metal.



Lap Weld

Horizontal lap joints are normally easy to weld with good bead appearance. The electrode can be pointed into the corner of the joint and the lower piece of metal acts as a ledge to support the molten metal. Care must be taken to avoid burning away the edge of the lap. Also, if the electrode angle is not correct, the arc flow can wash away the molten metal, causing undercuts. The joint should be welded with constant, uniform progress.

Other Weld Joints

As with oxyacetylene welding, your instructor may wish to demonstrate other welding joints. Arc welding practice will make you ---- better.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

CARPENTRY

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

CARPENTRY

Materials

Wood is one of our greatest natural resources. When cut into pieces that are uniform in thickness, width and length, it becomes lumber; the material most widely used for residential construction.

Lumber is the designation given to products of the sawmill and includes: boards used for flooring, sheathing, paneling, and trim; dimension lumber used for sills, plates, studs, rafters and other framing members; timbers used for posts, beams and heavy stringers; and numerous specialty items. The carpenter must have a good working knowledge of lumber--kinds, grades, sizes and other aspects that apply to its selection and use.

Kinds of Wood

Lumber may be classified as either softwood or hardwood. Softwood comes from the evergreen or needle bearing trees. These are called "conifers" because many of them bear cones. See figure 4-5. Hardwood comes from broadleaf (deciduous) trees that shed their leaves at the end of the growing season. This classification is somewhat confusing, however, because many of the hardwood trees produce a softer wood than some of the so-called softwood trees.

Several of the more common kinds of commercial softwoods and hardwoods are:

Softwoods	Hardwoods
Douglas Fir	Basswood
Southern Pine	Willow
Western Larch	American Elm
Hemlock	*Mahogany
White Fir	Sweet Gum
Spruce	*White Ash
Ponderosa Pine	Beech
Western Red Cedar	Birch
Redwood	Cherry
Cypress	Maple
White Pine	*Oak
Sugar Pine	*Walnut

*Open grained wood

A number of hardwoods have large pores in the cellular structure (called open grain woods) and require special or additional operations in the finishing procedure.

In addition to hardness and softness, different kinds of wood will vary in weight, strength, workability, color, texture, grain pattern and odor.

Availability of different species (kinds) of lumber varies somewhat throughout the country. This is especially true of framing lumber which is expensive to transport over long distances. It is usually more economical to select building materials (lumber, stone, etc.) that reflect the natural resources of the area.

Cutting Methods

Most lumber is cut in such a way that the annular rings form an angle of less than 45 deg. with the surface of the board. This method produces lumber that is called FLAT-GRAINED if it is softwood, or PLAIN-SAWED if it is hardwood. Minimum waste is incurred in using this method and desirable grain patterns are obrained.

Lumber can also be cut so the annular rings form an angle of more than 45 deg. with the surface of the board, figure 4-6. This method produces lumber that is called EDGE-GRAIN if it is softwood, and QUARTER-SAWED if it is hardwood. It is more difficult and expensive to use this method, but it does produce lumber that swells and shrinks less in width and is not so likely to warp.

Moisture Content and Shrinkage

Before wood can be used commercially, a large part of the moisture (sap) must be removed. When a living tree is cut, more than half of its weight may be moisture. Lumber used for framing and outside finish should be dried to a moisture content of about 15 percent. Most cabinet and furniture woods are dried to a moisture content of 7 to 10 percent.

The amount of moisture or moisture content (M.C.) in wood is expressed as a percent of the oven-dry weight. To determine the moisture content, a sample is first weighed. It is then placed in an oven and dried at a temperature of about 212 deg. F. The drying is continued until it no longer loses weight. The sample is weighed again and this oven-dry weight is subtracted from the initial weight. The difference is then divided by the ovendry weight, figure 4-7.

Moisture is contained in the cell cavities (free water) and in the cell walls (bound water). As the wood is dried, moisture frist leaves the cell cavities. When the cells are empty but the cell walls are still full of moisture, the wood has reached a condition called the FIBER SATURATION POINT. For most woods this is about 30 percent, figure 4-8.

The fiber saturation point is important because wood does not start to shrink until this point is reached. As the M.C. is reduced below 30 percent, moisture is removed from the cell walls and they become smaller in size. For a one percent moisture loss below the fiber saturation point, the wood will

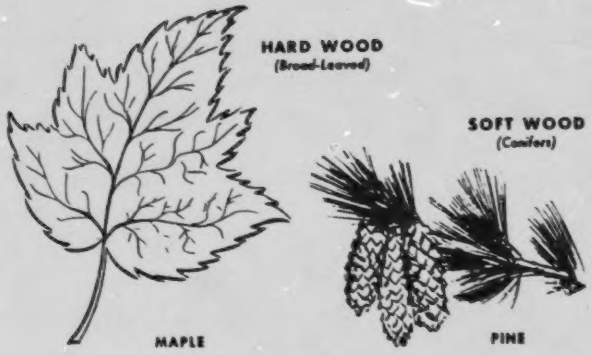

HARD WOOD
(Broad-Leaved)
SOFT WOOD
(Conifers)
MAPLE
PINE

Fig. 4-5. General classification of wood. (Paxton Lumber Co.)

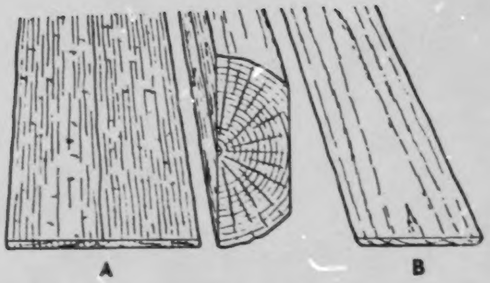
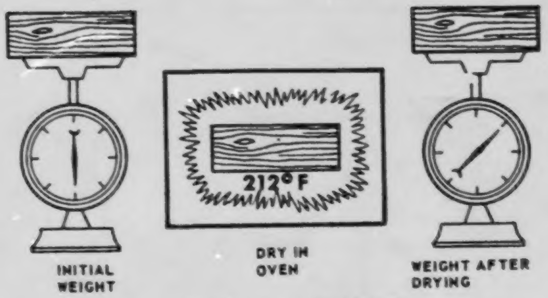


Fig. 4-6. Methods of cutting lumber. A—Edge-grain or quarter-sawed. B—Flat-grained or plain-sawed.


212° F
INITIAL WEIGHT
DRY IN OVEN
WEIGHT AFTER DRYING

$$\text{M. C.} = \frac{\text{INITIAL WT.} - \text{OVEN DRY WT.}}{\text{OVEN DRY WT.}}$$

Fig. 4-7. Determining moisture content of wood.

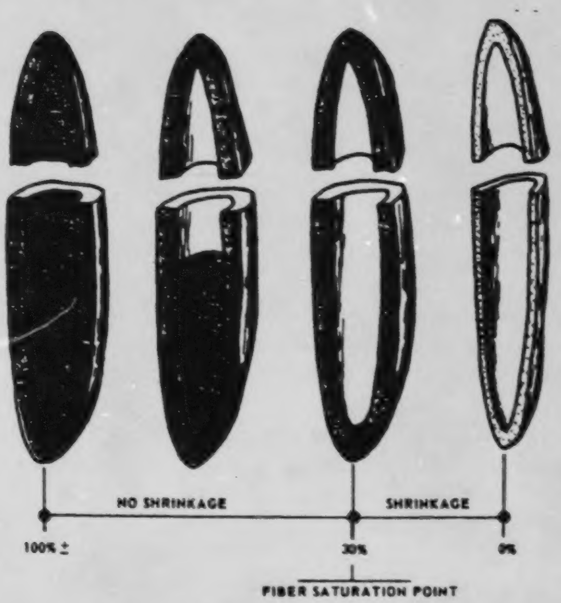

NO SHRINKAGE
SHRINKAGE
100% ±
30%
0%
FIBER SATURATION POINT

Fig. 4-8. How a wood cell dries. First the free water in the cell cavity is removed, and then the cell wall dries and shrinks.

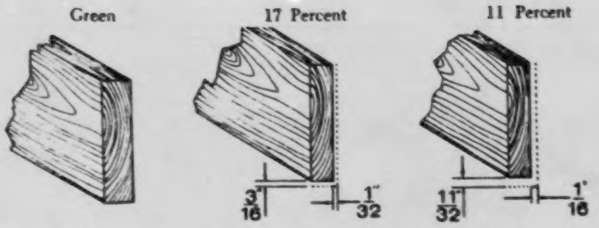

Green
17 Percent
11 Percent
3/16
1/32
11/32
1/16

Fig. 4-9. Dimensional change in a 2 x 10 joist.

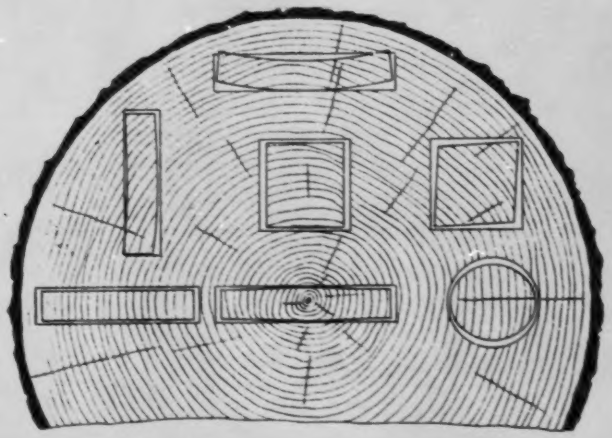


Fig. 4-10. The shrinkage and distortion of flat, square and round pieces, as affected by the direction of the annual rings.

shrink about 1/30th of the total possible shrinkage. If dried to 15 percent M.C., it will have been reduced by about one-half the total shrinkage. Figure 4-9 shows the shrinkage in a 2 x 10 joist.

Wood shrinks most along the direction of the annual rings (tangentially) and about one-half as much across these rings. There is practically no shrinkage in the length. How this shrinkage affects lumber cut from a log is shown in figure 4-10. As moisture is added to wood, it swells in the same proportion that the shrinkage has taken place.

Equilibrium Moisture Content

A piece of wood will give off or take on moisture from the air around it until the moisture in the wood is balanced with that in the air. At this point the wood is said to be at equilibrium moisture content (E.M.C.). Since wood is exposed to daily and seasonal changes in the relative humidity of the air, it is continually making slight changes in its moisture content and, therefore, changes in its dimensions. This is the reason doors and drawers often stick during humid weather but work freely the rest of the year.

Ideally, a wood structure should be framed with lumber at a M.C. equal to that which it will attain in service. This is not practical since lumber with such a low moisture content is seldom available and would likely gain moisture during the construction stages. Standard practice is to use lumber with a moisture content in the range of 15 to 19 percent. In heated structures, it will eventually reach a level of about 8 percent. However, this will vary in different geographical areas, figure 4-11.

The carpenter understands that some shrinkage is inevitable and makes allowances where it will affect the structure. The first, and by far the greatest change in moisture content occurs during the first year after construction, particularly during the first heating season.

When "green" lumber (in excess of 20 percent M.C.) is used, shrinkage will be excessive and it will be almost impossible to prevent excessive warping, plaster cracks, nail pops, squeaky floors and other difficulties.

Seasoning Lumber

This is the process of reducing the moisture content to the required level specified by the grade and use. In air-drying, the lumber is simply exposed to the outside air. It is carefully stacked with stickers (wood strips) between layers so air can ciruclate through the pole. Boards are also spaced apart in the layers so air can move vertically. Air-drying is a relatively slow process and often creates additional defects in the wood.

Lumber is kiln-dried by placing it in huge ovens where the temperature and humidity can be carefully controlled. When the green lumber is first placed in the kiln, steam is used to keep the humidity high while the temperature is kept at a low level. Gradually the temperature is raised and the humidity reduced. Fans are used to keep the air in constant circulation over the surface of the wood. See figure 4-12.

Lumber Defects

A defect is an irregularity occurring in or on wood that reduces its strength, durability or usefulness. It may or may not detract from appearance. For example, knots commonly considered a defect may add to the appearance of pine paneling. An imperfection that impairs only the appearance of wood is called a blemish. Some of the common defects include:

KNOTS: Caused by an imbedded branch or limb of the tree, figure 4-14. They are generally considered to be strength reducing - the amount depending upon the type, size and location, see figure 4-15.

SPLITS and CHECKS: A separation of the wood fibers along the grain and across the annular growth rings. Usually occurs at the ends of lumber - a result of uneven seasoning.

SHAKES: A separation along the grain and between the annular growth rings. Likely to occur only in species with abrupt change from spring to summer growth.

PITCH POCKETS: Internal cavities that contain or have contained pitch in either solid or liquid form.

HONEYCOMBING: Separation of the wood fibers in the interior section of the tree. May not be visible on the surface of boards.

WANE: The presence of bark or the absence of wood along the edge of the board. It forms a bevel and reduces the width.

BLUE STAIN: A discoloration caused by mold-like fungi. Objectional in appearance in some grades of lumber, but has little or no effect on strength.

DECAY: A disintegration of wood fibers due to fungi. Early stages of decay may be difficult to recognize. Advanced stages result in wood that is soft, spongy, and crumbles easily.

HOLES: Holes in lumber will lower the grade. They may be caused by handling equipment or by wood boring insects or worms.

WARP: Any variation from true or plane surface. May include any one or combination of the following: cup, bow, crook, and twist (also called wind). See figure 4-16.

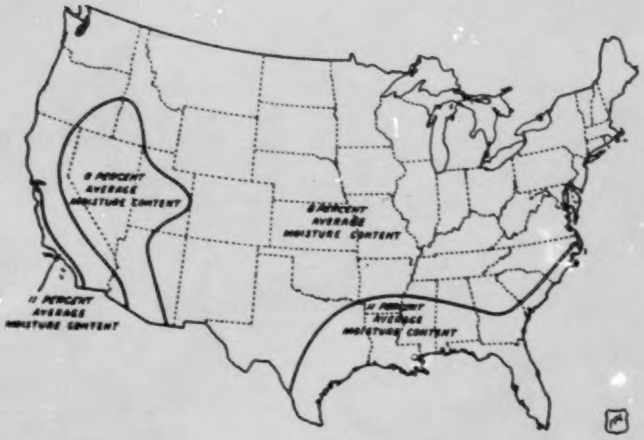

6 PERCENT AVERAGE MOISTURE CONTENT
8 PERCENT AVERAGE MOISTURE CONTENT
11 PERCENT AVERAGE MOISTURE CONTENT
11 PERCENT AVERAGE MOISTURE CONTENT

Fig. 4-11. Average moisture content of interior woodwork in various areas of the United States.

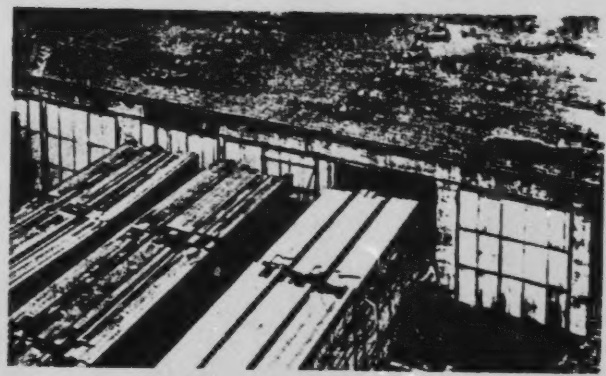


Fig. 4-12. Huge kilns used to season lumber at a modern sawmill. (Forest Products Lab.)

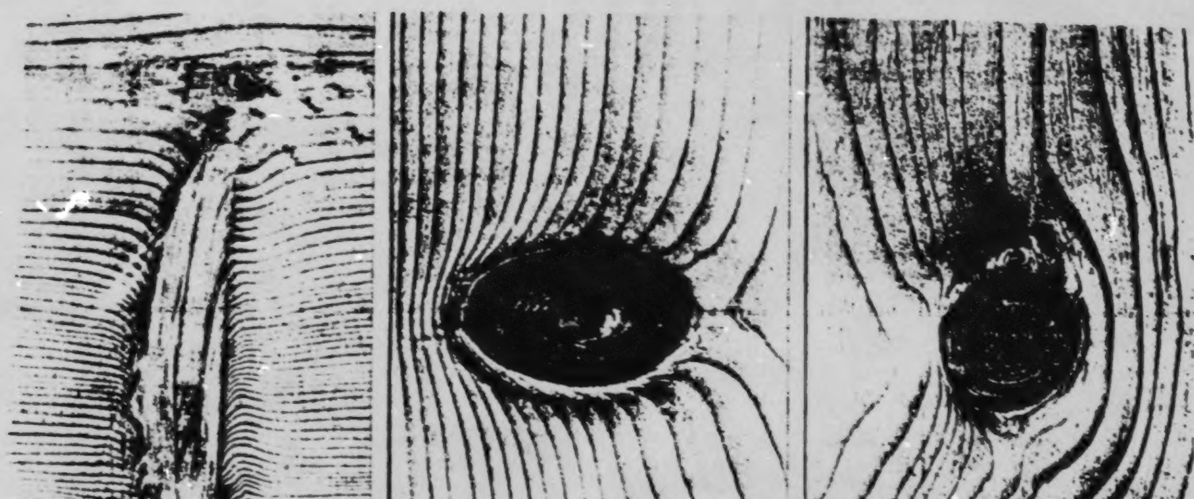


Fig. 4-14. Common kinds of knots. Left. Spike. Center. Intergrown. Right. Encased. An encased knot will usually loosen and fall out. (Forest Products Lab.)

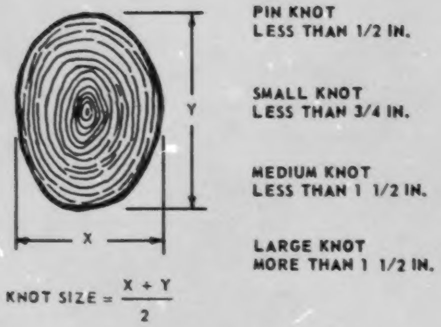


Fig. 4-15. Knot sizes.

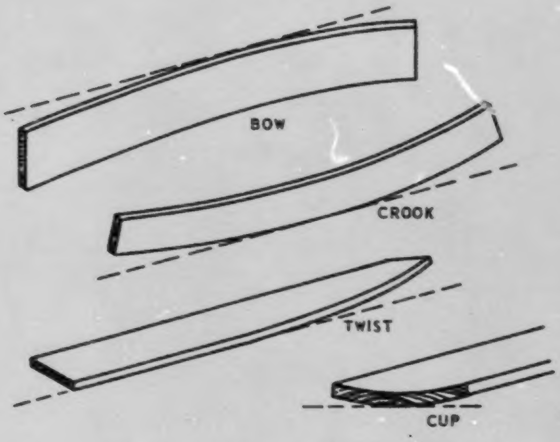


Fig. 4-16. Kinds of warp.

Grades (Softwoods)

Basic principles of grading lumber are formulated by the American Lumber Standards Committee and are published by the U.S. Department of Commerce. Detailed rules are developed and applied by the various associations of lumber producers - Western Wood Products Association, Southern Pine Inspection Bureau, California Redwood Association and others. These agencies publish and distribute grading rules for the species of lumber produced in their regions and maintain qualified personnel who supervise grading standards at sawmille.

Basic classifications of softwood grading include boards, dimension, and timbers. The grades within these classifications are shown in figure 4-17. Another classification called FACTORY and SHOP LUMBER is graded primarily for remanufacturing purposes. It is used by millwork plants in the fabrication of windows, doors, moldings and other trim items.

The carpenter must understand that quality construction does not require that all lumber be of the best grade. Today, lumber is graded for specific uses and, in a given structure, several grades may be appropriate. The key to good economical construction is the proper use of the lowest grade which is suitable for the purpose.

Grades (Hardwoods)

Grades for hardwood lumber are established by the National Hardwood Lumber Associatin. FAS (firsts and seconds) is the best grade and specifies that pieces be no less than 6 in. wide by 8 ft. long - and yield at least 83 1/3 percent clear cuttings. The next lower grade is SELECTS and permits pieces 4 in. wide by 6 ft. long. A still lower grade is designated as NO. 1 COMMON and is expected to yield 66 2/3 percent clear cuttings.

boards

			ALTERNATE BOARD GRADES
APPEARANCE GRADES	**SELECTS**	B & BETTER (IWP—SUPREME) C SELECT (IWP—CHOICE) D SELECT (IWP—QUALITY)	
	FINISH	SUPERIOR PRIME E	
	PANELING	CLEAR (ANY SELECT OR FINISH GRADE) NO. 2 COMMON SELECTED FOR KNOTTY PANELING NO. 3 COMMON SELECTED FOR KNOTTY PANELING	
	SIDING (BEVEL, BUNGALOW)	SUPERIOR PRIME	
BOARDS SHEATHING		NO. 1 COMMON (IWP—COLONIAL) NO. 2 COMMON (IWP—STERLING) NO. 3 COMMON (IWP—STANDARD) NO. 4 COMMON (IWP—UTILITY)	SELECT MERCHANTABLE CONSTRUCTION STANDARD UTILITY

SPECIFICATION CHECK LIST

- ☐ Grades listed in order of quality.
- ☐ Include all species suited to project.
- ☐ For economy, specify lowest grade that will satisfy job requirement.
- ☐ Specify surface texture desired.
- ☐ Specify moisture content suited to project.
- ☐ Specify Ⓦ grade stamp. For finish and exposed pieces, specify stamp on back or ends.

WESTERN RED CEDAR

FINISH PANELING AND CEILING	CLEAR HEART A B
BEVEL SIDING	CLEAR — V.G. HEART A — BEVEL SIDING B — BEVEL SIDING C — BEVEL SIDING

dimension

LIGHT FRAMING 2" to 4" Thick 2" to 4" Wide	CONSTRUCTION STANDARD UTILITY ECONOMY	This category for use where high strength values are **NOT** required; such as studs, plates, sills, cripples, blocking, etc.
STUDS 2" to 4" Thick 2" to 4" Wide	STUD ECONOMY STUD	An optional all-purpose grade limited to 10 feet and shorter. Characteristics affecting strength and stiffness values are limited so that the "Stud" grade is suitable for all stud uses, including load bearing walls.
STRUCTURAL LIGHT FRAMING 2" to 4" Thick 2" to 4" Wide	SELECT STRUCTURAL NO. 1 NO. 2 NO. 3 ECONOMY	These grades are designed to fit those engineering applications where higher bending strength ratios are needed in light framing sizes. Typical uses would be for trusses, concrete pier wall forms, etc.
STRUCTURAL JOISTS & PLANKS 2" to 4" Thick 6" and Wider	SELECT STRUCTURAL NO. 1 NO. 2 NO. 3 ECONOMY	These grades are designed especially to fit in engineering applications for lumber six inches and wider, such as joists, rafters and general framing uses.

timbers

BEAMS & STRINGERS	SELECT STRUCTURAL NO. 1 NO. 2 (NO. 1 MINING) NO. 3 (NO. 2 MINING)	**POSTS & TIMBERS**	SELECT STRUCTURAL NO. 1 NO. 2 (NO. 1 MINING NO. 3 (NO. 2 MINING)

Fig. 4-17. Softwood lumber classifications and grades. Grade titles and specifications will vary among lumber manufacturers' associations and regions producing lumber.

Lumber Stress Values

In softwood lumber, all dimension and timber grades except Economy and Mining are assigned stress values. Slope of grain, know sizes and knot locations are critical considerations. There are two methods of assigning stress values, "visual" and "machine rated". In the latter method, lumber is fed into a special machine and subjected to bending forces. The stiffness of each piece (modulus of elasticity E) is measured and marked on each piece. Machine stress-rated lumber (MSR) must also meet certain visual requirements.

Lumber Sizes

When listing and caluclating the size and amount of lumber, the nominal dimension is always used. Figure 4-18 illustrates the nominal and dressed sizes for various classifications of lumber used by the carpenter. Note that nominal sizes are sometimes listed in quarters. For example: 1 1/4 in. material is given as 5/4. This nominal dimension is its rough unfinished measurement, figure 4-19. The dressed size is less than the nominal size as a result of seasoning and surfacing. Dressed sizes of lumber are established by the American Lumber Standards and applied consistently throughout the industry.

Figuring Board Footage

The unit of measure for lumber is the board foot. This is a piece 1 in. thick and 12 in. square or its equivalent (144 cu.in.) Standard size pieces can be quickly calculated by visualizing the board feet included. For example: a board 1 x 12 and 10 ft. long will contain 10 bd. ft. If it were only 6 in. wide, it would be 5 bd. ft. If the original board had been 2 in. thick, it would have contained 20 bd. ft. The following formula can be applied to any size piece where the total length is given in feet:

$$\text{Bd. ft.} = \frac{\text{No. pcs.} \times T \times W \times L}{12}$$

An example of the application of the formula is shown below. Find the number of board feet in 6 pieces of lumber that measure 1" x 8" x 14':

$$\text{Bd.ft.} = \frac{\overset{1}{\cancel{6}} \times 1 \times \overset{4}{\cancel{8}} \times 14}{\underset{\underset{1}{\cancel{2}}}{\cancel{12}}} = 56 = 56 \text{ bd. ft.}$$

Stock that is less than 1 in. thick is figured as though it were 1 in. When the stock is thicker than 1 in., the nominal size is used. When this size contains a fraction such as 1 1/4, change it to an improper fraction (5/4) and place the numerator above the formula line and the denominator below. For example: find the board footage in 2 pieces of lumber that measure 1 1/4" x 10" x 8'.

IV-S-106

BOARD MEASURE

The term "board measure" indicates that a board foot is the unit for measuring lumber. A board foot is one inch thick and 12 inches square.

The number of board feet in a piece is obtained by multiplying the nominal thickness in inches by the nominal width in inches by the length in feet and dividing by 12: $\frac{(T \times W \times L)}{12}$

Lumber less than one inch in thickness is figured as one-inch.

product classification

	thickness in.	width in.		thickness in.	width in.
board lumber	1″	2″ or more	**beams & stringers**	5″ and thicker	more than 2″ greater than thickness
light framing	2″ to 4″	2″ to 4″	**posts & timbers**	5″ x 5″ and larger	not more than 2″ greater than thickness
studs	2″ to 4″	2″ to 4″ 10′ and shorter	**decking**	2″ to 4″	4″ to 12″ wide
structural light framing	2″ to 4″	2″ to 4″	**siding**	thickness expressed by dimension of butt edge	
joists & planks	2″ to 4″	6″ and wider	**mouldings**	size at thickest and widest points	
Standard lengths of lumber generally are 6 feet and longer in multiples of 1′					

dimensional data / nominal, dressed, based on 1970 rules

Product	Description	Nominal Size		Dressed Dimensions		
				Thicknesses and Widths In.		
		Thickness In.	Width In.	Surfaced Dry	Surfaced Unseasoned	Lengths Ft.
FRAMING	S4S	2 3 4	2 3 4 6 8 10 12 Over 12	1-½ 2-½ 3-½ 5-½ 7-¼ 9-¼ 11-¼ Off ¾	1-9/16 2-9/16 3-9/16 5-⅝ 7-½ 9-½ 11-½ Off ½	6 ft. and longer in multiples of 1′
				Thickness In.	Width In.	
TIMBERS	Rough or S4S	5 and Larger		½ Off Nominal		Same
		Nominal Size		Dressed Dimensions Surfaced Dry		
		Thickness In.	Width In.	Thickness In.	Width In.	Lengths Ft.
DECKING Decking is usually surfaced to single T&G in 2″ thickness and double T&G in 3″ and 4″ thicknesses	2″ Single T&G	2	6 8 10 12	1½	5 6¾ 8¾ 10¾	6 ft. and longer in multiples of 1′
	3″ and 4″ Double T&G	3 4	6	2½ 3½	5¼	
FLOORING	(D & M), (S2S & CM)	⅜ ½ ⅝ 1 1¼ 1½	2 3 4 5 6	5/16 7/16 9/16 ¾ 1 1¼	1⅛ 2⅛ 3⅛ 4⅛ 5⅛	4 ft. and longer in multiples of 1′
CEILING AND PARTITION	(S2S & CM)	⅜ ½ ⅝ ¾	3 4 5 6	5/16 7/16 9/16 11/16	2⅛ 3⅛ 4⅛ 5⅛	4 ft. and longer in multiples of 1′
FACTORY AND SHOP LUMBER	S2S	1 (4/4) 1¼ (5/4) 1½ (6/4) 1¾ (7/4) 2 (8/4) 2½ (10/4) 3 (12/4) 4 (16/4)	5 and wider (4″ and wider in 4/4 No. 1 Shop and 4/4 No. 2 Shop)	25/32 (4/4) 1 5/32 (5/4) 1 13/32 (6/4) 1 19/32 (7/4) 1 13/16 (8/4) 2⅜ (10/4) 2¾ (12/4) 3¾ (16/4)	Usually sold random width	4 ft. and longer in multiples of 1′

ABBREVIATIONS

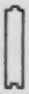
Abbreviated descriptions appearing in the size table are explained below.

S1S — Surfaced one side.
S2S — Surfaced two sides.
S4S — Surfaced four sides.
S1S1E — Surfaced one side, one edge.
S1S2E — Surfaced one side, two edges
CM — Center matched.
D & M — Dressed and matched.
T & G — Tongue and grooved.
EV1S — Edge vee on one side.
S1E — Surfaced one edge.

Fig. 4-18. Standard lumber sizes. (Western Wood Products Assoc.)

coverage estimator

The following estimator provides factors for determining the exact amount of material needed for the five basic types of wood paneling. Multiply square footage to be covered by factor (length x width x factor).

		Nominal Size	WIDTH		AREA FACTOR*
			Overall	Face	
SHIPLAP		1 x 6	5½	5⅛	1.17
		1 x 8	7¼	6⅞	1.16
		1 x 10	9¼	8⅞	1.13
		1 x 12	11¼	10⅞	1.10
TONGUE AND GROOVE		1 x 4	3⅜	3⅛	1.28
		1 x 6	5⅜	5⅛	1.17
		1 x 8	7⅛	6⅞	1.16
		1 x 10	9⅛	8⅞	1.13
		1 x 12	11⅛	10⅞	1.10
S4S		1 x 4	3½	3½	1.14
		1 x 6	5½	5½	1.09
		1 x 8	7¼	7¼	1.10
		1 x 10	9¼	9¼	1.08
		1 x 12	11¼	11¼	1.07

		Nominal Size	WIDTH		AREA FACTOR*
			Overall	Face	
PANELING PATTERNS		1 x 6	5⁷⁄₁₆	5¹⁄₁₆	1.19
		1 x 8	7⅛	6¾	1.19
		1 x 10	9⅛	8¾	1.14
		1 x 12	11⅛	10¾	1.12
BEVEL SIDING		1 x 4	3½	3½	1.60
		1 x 6	5½	5½	1.33
		1 x 8	7¼	7¼	1.28
		1 x 10	9¼	9¼	1.21
		1 x 12	11¼	11¼	1.17

*Allowance for trim and waste should be added.

Product	Description	Nominal Size		Dressed Dimensions		
		Thickness In.	Width In.	Thickness In.	Width In.	Lengths Ft.
SELECTS AND COMMONS S-DRY	S1S, S2S, S4S, S1S1E, S1S2E....	4/4 5/4 6/4 7/4 8/4 9/4 10/4 11/4 12/4 16/4	2 3 4 5 6 7 8 and wider	¾ 1⁵⁄₃₂ 1¹³⁄₃₂ 1¹⁹⁄₃₂ 1¹³⁄₁₆ 2³⁄₃₂ 2⅜ 2⁹⁄₁₆ 2¾ 3¾	1½ 2½ 3½ 4½ 5½ 6½ ¾ Off nominal	6 ft. and longer in multiples of 1′
FINISH AND BOARDS S-DRY	S1S, S2S, S4S, S1S1E, S1S2E ...	1 1¼ 1½	2 3 4 5 6 7 8 and wider	¾ 1 1¼	1½ 2½ 3½ 4½ 5½ 6½ ¾ off nominal	3′ and longer. In Superior grade, 3% of 3′ and 4′ and 7% of 5′ and 6′ are permitted. In Prime grade, 20% of 3′ to 6′ is permitted.
RUSTIC AND DROP SIDING	(D & M) .... If ⅜″ or ½″ T & G specified, same over-all widths apply. (Shiplapped, ⅜-in. or ½-in. lap) ..	1	6 8 10 12	²³⁄₃₂	5⅜ 7⅛ 9⅛ 11⅛	4 ft. and longer in multiples of 1′
PANELING AND SIDING	T&G or Shiplap..................	1	6 8 10 12	²³⁄₃₂	5⁷⁄₁₆ 7⅛ 9⅛ 11⅛	Same
CEILING AND PARTITION	T&G	⅝ 1	4 6	⁹⁄₁₆ ²³⁄₃₂	3⅜ 5⅜	Same
BEVEL SIDING	Bevel or Bungalow Siding........	½	4 5 6	¹⁵⁄₃₂ butt, ³⁄₁₆ tip	3½ 4½ 5½	Same
	Western Red Cedar Bevel Siding available in ½″, ⅝″, ¾″ nominal thickness. Corresponding thick edge is ¹⁵⁄₃₂″, ⁹⁄₁₆″ and ¾″. Widths for 8″ and wider, ½″ off nominal.	¾	8 10 12	¾ butt, ³⁄₁₆ tip	7¼ 9¼ 11¼	

See coverage estimator chart above for T&G widths.

MINIMUM ROUGH SIZES Thicknesses and Widths Dry or Unseasoned All Lumber (S1E, S2E, S1S, S2S)

80% of the pieces in a shipment shall be at least ⅛″ thicker than the standard surfaced size, the remaining 20% at least ³⁄₃₂″ thicker than the surfaced size. Widths shall be at least ⅛″ wider than standard surfaced widths.

When specified to be full sawn, lumber may not be manufactured to a size less than the size specified.

$$\text{Bd.ft.} = \frac{\overset{1}{\cancel{2}} \times 5 \times \overset{5}{\cancel{10}} \times \overset{2}{\cancel{8}}}{\underset{\underset{1}{\cancel{2}}}{\cancel{4}} \quad \underset{3}{\cancel{12}}} = \frac{50}{3} = 16\ 2/3 \text{ bd. ft.}$$

Use the nominal size of the material when figuring the footage. Items such as moldings, furring strips, and grounds are priced and sold by the lineal foot; thickness and width are disregarded.

Plywood

Plywood is constructed by gluing together a number of layers (plies) of wood with the grain direction turned at right angles in each successive layer. An odd number (3,5,7) of plies are used so they will be balanced on either side of a center core and so the grain of the outside layers will run in the same direction. The outer plies are called FACES or face and back. The next layers under these are called CROSS-BANDS and the other inside layer or layers are called the CORE. See figure 4-20. A thin plywood panel made of three layers would consist of two faces and a core.

There are two basic types of plywood; exterior and interior. EXTERIOR PLYWOOD is bonded with waterproof glues and can be used for siding,concrete forms, and other constructions that will be exposed to the weather or excessive moisture. INTERIOR PLYWOOD is bonded with glues that are not waterproof and is used for cabinets and other inside work where the moisture content of the panels will not exceed 20 percent.

Plywood can be secured in thicknesses of 1/8 in. to more than 1 ins. with the common sizes being 1/4, 3/8, 1/2, 5/8 and 3/4 in. A standard panel size is 4 ft. wide by 8 ft. long. Smaller size panels are available in the hardwoods.

Plywood Grades (Softwood)

Softwood plywood for general construction is manufactured in accordance with U.S. Product Standard PSI. This standard provides a system for designating the species, strength, type of glue, and appearance.

Many species of softwood are used in the manufacture of plywood and are separated into five groups - based on their stiffness and strength. Group 1 lists the species with the highest level of these characteristics, figure 4-21. A lettering system is used to designate the quality of veneer used on the panel face, back and for the inner ply construction. The N grade is the highest grade and ranges downward through A to including D. See figure 4-22.

The American Plywood Association (APA) conducts a rigid testing program based on PSI-74 and member manufacturing companies are

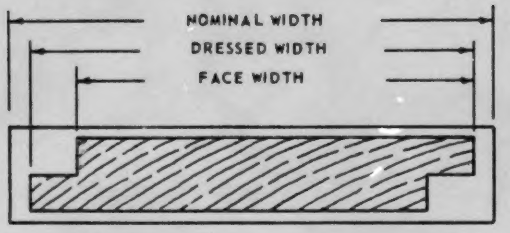


Fig. 4-19. Nominal and dressed sizes.

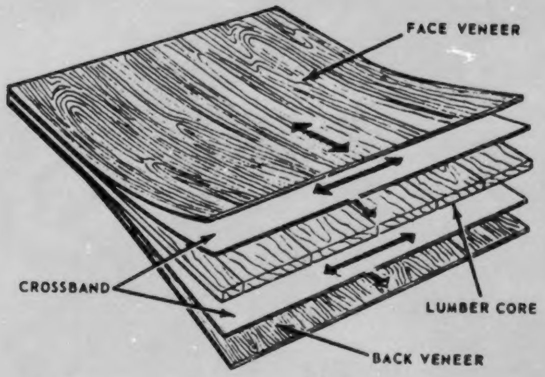


Fig. 4-20. Plywood construction. Hardwood or softwood classification depends on the kind of wood used for the face veneers.

Group 1	Group 2	Group 3	Group 4	Group 5
Apitong Beech, American Birch Sweet Yellow Douglas Fir 1[a] Kapur Keruing Larch, Western Maple, Sugar Pine Caribbean Ocote Pine, South. Loblolly Longleaf Shortleaf Slash Tanoak	Cedar, Port Orford Cypress Douglas Fir 2 Fir California Red Grand Noble Pacific Silver White Hemlock, Western Lauan Almon Bagtikan Mayapis Red Lauan Tangile White Lauan Maple, Black Mengkulang Meranti, Red Mersawa Pine Pond Red Virginia Western White Spruce Red Sitka Sweetgum Tamarack Yellow poplar	Alder, Red Birch, Paper Cedar, Alaska Fir, Subalpine Hemlock, Eastern Maple, Bigleaf Pine Jack Lodgepole Ponderosa Spruce Redwood Spruce Black Engelmann White	Aspen Bigtooth Quaking Cativo Cedar Incense Western Red Cottonwood Eastern Black (Western Poplar) Pine Eastern White Sugar	Basswood Fir, Balsam Poplar, Balsam

Fig. 4-21. Classification of softwood species. (American Plywood Assoc.)

N	Smooth surface "natural finish" veneer. Select, all heartwood or all sapwood. Free of open defects. Allows not more than 6 repairs, wood only, per 4 x 8 panel, made parallel to grain and well matched for grain and color.
A	Smooth, paintable. Not more than 18 neatly made repairs, boat, sled, or router type, and parallel to grain, permitted. May be used for natural finish in less demanding applications.
B	Solid surface. Shims, circular repair plugs and tight knots to 1 inch permitted. Wood or synthetic patching material may be used. Some minor splits permitted.
C (Plugged)	Improved C veneer with splits limited to 1/8 inch width and knotholes and borer holes limited to 1/4 x 1/2 inch. Admits some broken grain. Synthetic repairs permitted.
C	Tight knots to 1-1/2 inch. Knotholes to 1 inch and some to 1-1/2 inch if total width of knots and knotholes is within specified limits. Synthetic or wood repairs. Discoloration and sanding defects that do not impair strength permitted. Limited splits allowed.
D	Knots and knotholes to 2-1/2 inch width and 1/2 inch larger within specified limits. Limited splits are permitted.

Fig. 4-22. Veneer grades of softwood plywood. (American Plywood Assoc.)

licensed to use their official grade-trademark. These grade-trademarks are stamped on each panel and cover both appearance grades and engineered (structural) classifications.

A typical grade-trademark for an engineered grade of plywood is shown in figure 4-23. The C-D indicates that a C grade of veneer has been used on the face of the panel and a D grade on the back. Some engineered grades include an identification index which consists of a pair of numbers separated by a slash mark (/). The number on the left indicates the maximum recommended spacing of supports in inches when the plywood is used for roof decking. The number on the right indicates the maximum recommended spacing when the plywood is used for subflooring. In general, the higher the index number, the greater the stiffness.

Figure 4-24 lists some engineered grades of plywood and includes descriptions and most common uses. A more complete list can be secured from the American Plywood Association. A table listing appearance grades of plywood is included in the appendix.

Plywood Grades (Hardwood)

The Hardwood Plywood Institute uses a number system for grading the faces and backs of a panel. A grading specification of 1-2 would indicate a good face with grain carefully matched and a good back but without careful grain matching. A number 3 back would permit noticeable defects and patching but would be generally sound. A special or PREMIUM grade of hardwood is known as "architectural" or "sequence-matched". This usually requires an order to a plywood mill for a series of matched plywood panels.

For either softwood or hardwood plywood, it is common practice to designate in a general way the grade by the symbol G2S (good two sides) or G1S (good one side).

In addition to the various kinds, types, and grades, hardwood plywood is made with different core constructions. The two most common are the veneer core and the lumber core as shown in figure 4-25. VENEER CORES are the least expensive and are fairly stable and warp resistant. LUMBER CORES are easier to cut, the edges are better for shaping and finishing, and they hold nails and screws better. Plywood is also manufactured with a particle board core. It is made by gluing veneers directly to the particle board surface.

Hardboard and Particle Board

Hardboards and particle boards are used extensively in modern construction for siding and interior wall surfaces. In cabinetwork they serve as appropriate materials for drawer bottoms and concealed panels in cases, cabinets and chests. Figure 4-26 shows some of the various types of hardboards and particle boards that are available. These are manufactured by many different companies and are sold under various trade names.

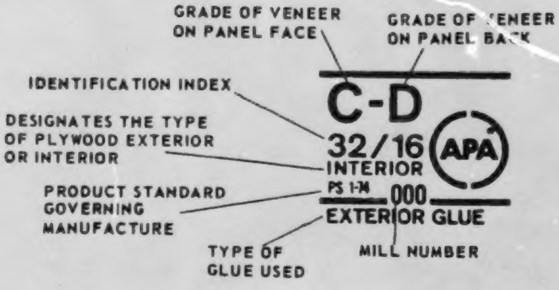

GRADE OF VENEER ON PANEL FACE
GRADE OF VENEER ON PANEL BACK
IDENTIFICATION INDEX
DESIGNATES THE TYPE OF PLYWOOD EXTERIOR OR INTERIOR
PRODUCT STANDARD GOVERNING MANUFACTURE
TYPE OF GLUE USED
MILL NUMBER
C-D
32/16
APA
INTERIOR
PS 1-74
000
EXTERIOR GLUE

Fig. 4-23. Typical grade-trademark for plywood manufactured in compliance with U.S. Product Standard PSI-74. (American Plywood Assoc.)

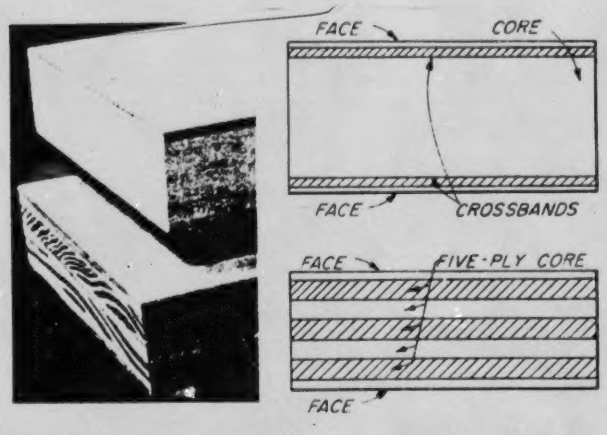
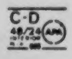
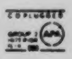
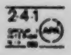

FACE
CORE
FACE
CROSSBANDS
FACE
FIVE-PLY CORE
FACE

Fig. 4-25. Hardwood plywood. Above. Lumber core. Below. Veneer core.

INTERIOR TYPE

Use these terms when you specify plywood	Description and Most Common Uses	Typical Grade-trademarks	Veneer Grade			Most Common Thicknesses (inch) (2) (3)					
			Face	Back	Inner Plies						
C-D INT-APA (1) (4)	For wall and roof sheathing, subflooring, industrial uses such as pallets. Also available with intermediate glue or exterior glue. Specify intermediate glue if moderate construction delays are expected; exterior glue for better durability in somewhat longer construction delays, and for wood foundations.		C	D	D		5/16	3/8	1/2	5/8	3/4
STRUCTURAL I C-D INT APA (4) and STRUCTURAL II C-D INT-APA (4)	Unsanded structural grades where plywood strength properties are of maximum importance: structural diaphragms, box beams, gusset plates, stressed-skin panels, containers, pallet bins. Made only with exterior glue.		C	D	D		5/16	3/8	1/2	5/8	3/4
C-D PLUGGED INT-APA (1) (4) (5)	For built-ins, wall and ceiling tile backing, cable reels, walkways, separator boards. Not a substitute for Underlayment, as it lacks Underlayment's punch-through resistance. Touch-sanded.		C Plgd.	D	D		5/16	3/8	1/2	5/8	3/4
2•4•1 INT-APA (1) (6)	Combination subfloor-underlayment. Quality base for resilient floor coverings, carpeting, wood strip flooring. Use 2•4•1 with exterior glue in areas subject to moisture. Unsanded or touch-sanded as specified.		C Plgd.	D	C & D		(available 1-1/8" or 1-1/4")				
EXTERIOR TYPE											
C-C EXT-APA (4)	Unsanded grade with waterproof bond for subflooring and roof decking, siding on service and farm buildings, wood foundations, crating, pallets, pallet bins, cable reels.		C	C	C		5/16	3/8	1/2	5/8	3/4
STRUCTURAL I C-C EXT-APA (7) (4) and STRUCTURAL II C-C EXT-APA (7) (4)	For engineered applications in construction and industry where full Exterior type panels are required. Unsanded. See (5) for Group requirements.		C	C	C		5/16	3/8	1/2	5/8	3/4

(1) Also available with exterior or intermediate glue (check dealer for availability of intermediate glue in your area).

(2) All grades available tongue-and-grooved in panels 1/2" and thicker.

(3) Panels are standard 4x8-foot size. Other sizes available.

(4) May be grade-trademarked with identification index.

(5) Also available in Structural I (all plies limited to Group 1 species) and Structural II (all plies limited to Group 1, 2, or 3 species).

(6) Available in Group 1, 2, or 3 only.

(7) Also available in Exterior sanded grades.

Fig. 4-24. Selected list of engineered grades of softwood plywood. Appearance grades are listed in the appendix. (American Plywood Assoc.)

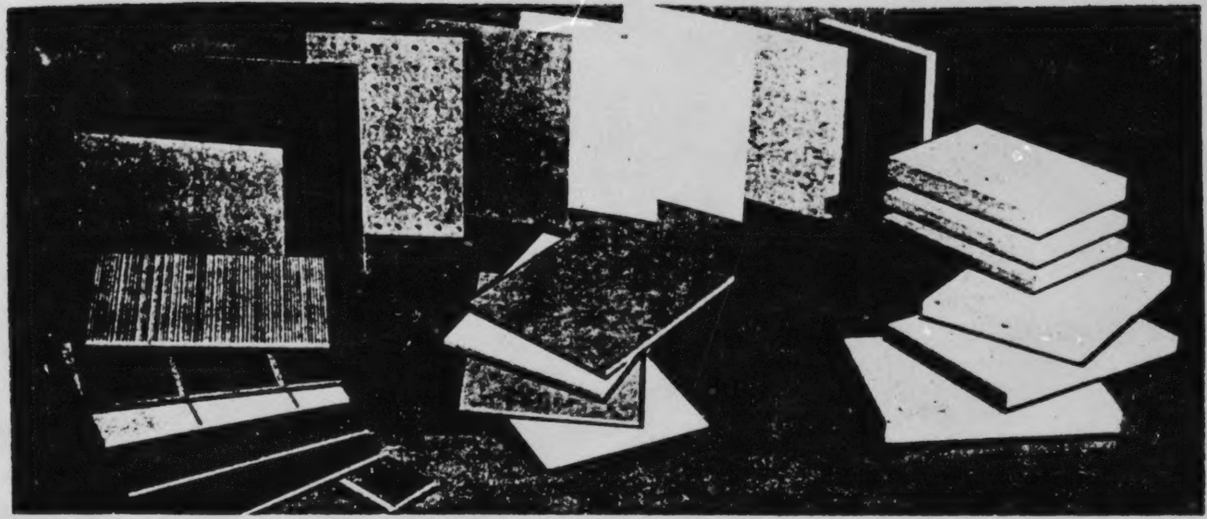


Fig. 4-26. Manufactured materials. Left. Hardboard. Right. Particle board. (Weyerhaeuser Co.)

Hardboard is made of refined wood fibers, pressed together to form a hard, dense material (50-8- lbs. per cu. ft.). There are two types; standard and tempered. Tempered hardboard is impregnated with oils and resins that make it harder, slightly heavier, more water resistant and darker in appearance. Hardboard is manufactured with one side smooth (S1S) or both sides smooth (S2S). It is available in thicknesses from 1/12 in. to 5/16 in. with the most common thicknesses being 1/8, 3/16 and 1/4 in. Panels are 4 ft. wide and come in standard lengths of 8, 10, 12 and 16 ft.

Particle board is made of wood flakes, chips and shavings bonded together with resins or adhesives. It is not as heavy as hardboard (about 40 lbs. per cu. ft.) and is available in thicker pieces. Particle board may be constructed of layers made of different size wood particles; large ones in the center to provide strength and fine ones at the surface to provide smoothness. Extensive use is made of particle board as a base for plastic laminates and as a core for plywood. It is available in a wide range of thicknesses from 1/4 in. to 1 7/16 in. The most cimmon panel size is 4 x 8 ft.

The unit of measure for plywood, hardboard and particle board is the square foot (sq. ft.). A standard 4 ft x 8 ft panel contains 32 sq. ft. Prices are quoted per square foot on the basis of full panel purchase and vary widely depending on the kind, thickness and grade.

Wood Treatments

Wood and wood products can be protected from attack by fungi, insects and borers by the application of special chemicals or wood preservatives. The degree of protection depends on the effectiveness of the chemical and how thoroughly it penetrates the material. Millwork plants employ extensive treatment processes in the manufacture of such items as door frames and window units.

There are two general classes of wood preservatives: oils, such as creosote, and petroleum solutions of pentachlorophenol; and certain salts that can be dissolved in water The selection of a preservative should be based on its effectiveness in protecting the wood and also on any side effects that may result - discoloration of painted surfaces or objectionable odors.

A number of commercially prepared preservatives are available for on-the-job application. Study the manufacturer's directions and recommendations carefully. Use special precautions in handling solutions since some contain toxic chemicals and may also create a fire or explosion hazard during application.

Nonwood Materials

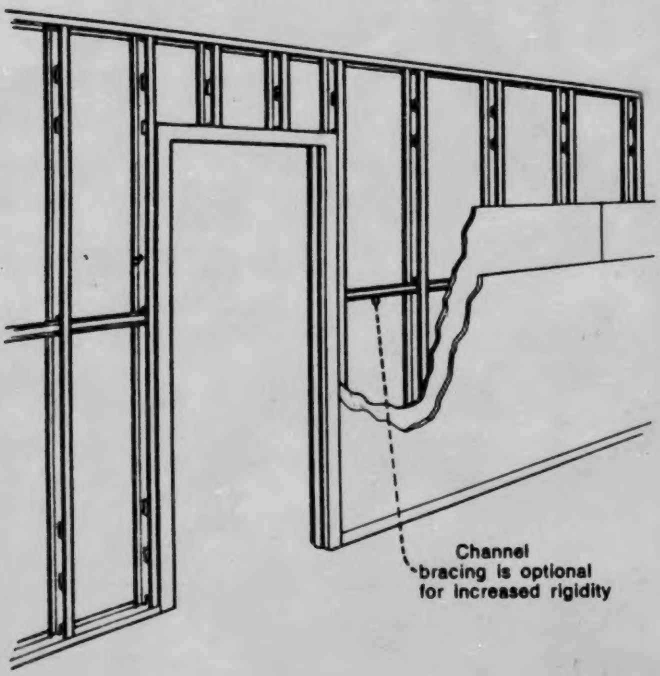
The carpenter works with a number of materials other than the lumber and wood-base products previously discussed. Some of the more common items include gypsum lath, wallboard, and sheathing; insulation boards and blankets; shingles made of mineral fiber and asphalt; metal lath and flashing units; and a wide range of resilient flooring materials.

METAL STUDS are another example of a nonwood material. Originally designed for commercial and institutional construction, their use is now being extended to residential structures. A typical stud consists of a metal channel with openings through which electrical and plumbing lines can be installed. See figure 4-27. These are attached to base and ceiling channels with metal screws or clips. Wall surface material is attached to the stud using self-drilling drywall screws. Some web-type studs have a special metal edge into which nails can be driven. Metal stud systems are usually designed for nonload bearing walls and partitions.

Handling and Storing

Building materials are expensive and every precaution should be taken to maintain them in good condition. After they are delivered to the construction site, this becomes the responsibility of the carpenter.

Piles of framing lumber and sheathing should be laid on level skids raised at least 6 in. above the ground. Be sure all pieces are well supported and are lying straight. Cover the material with canvas or waterproof paper, laid to shed water. Polyethylene film provides a watertight covering, **figure** 4-28.



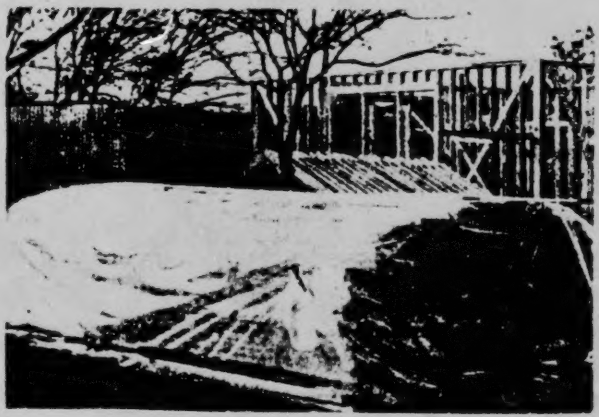


Fig. 4-28. Using polyethylene film to cover framing materials.

Sawing

In woodworking, it is important that you learn how to use tools properly and safely.

In working with saws be sure to select the proper saw for the job. All saws should be sharp and in good condition. Information on power-operated saws is included so you may see how they are constructed and operated.

Coping Saw - The coping saw is used mostly to cut around curves in stock one inch or less in thickness. While sawing, take quick, easy strokes using only enough forward pressure to keep the saw cutting. Hold the saw straight to help prevent binding.

Two methods are commonly used. If you are using THIN stock (3/8 in. or less in thickness), fasten a V-block as a platform to a bench with a clamp, or in a vise. Using this method, the saw cuts best with a downward stroke set the teeth of the blade point toward the handle, figure 5-1. If you are using THICKER stock (1/2 in. or more), fasten it in a vise. Using this method, the saw cuts best with a forward stroke with the saw teeth pointing AWAY from the handle, figure 5-2.

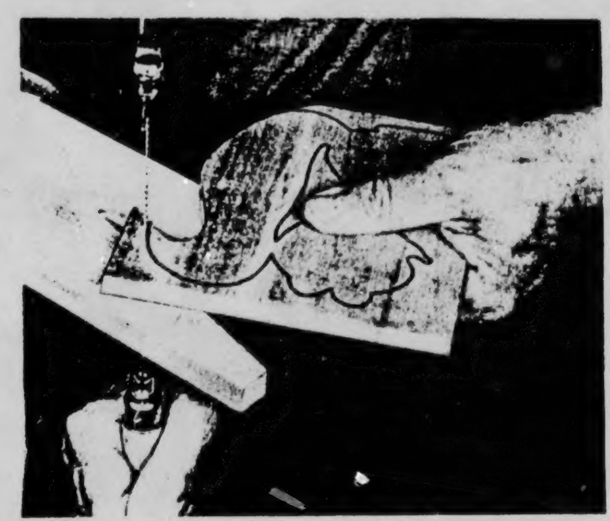


Fig. 5-1. Sawing thin stock with a coping saw and V-block.

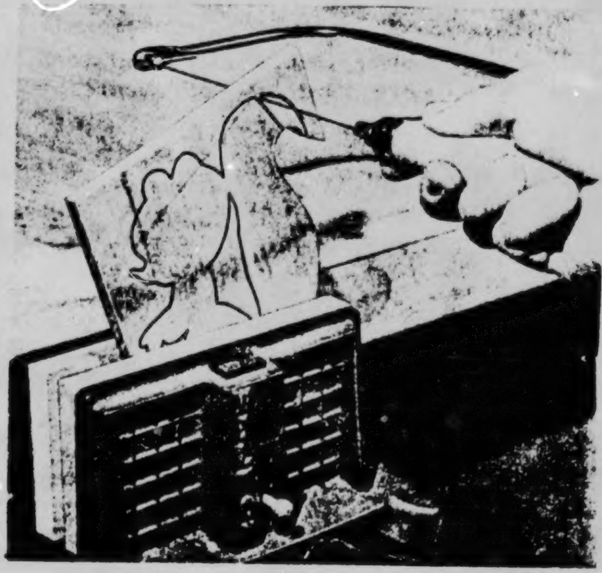


Fig. 5-2. Sawing a curve with a coping saw and vise.

Blades may be of the pin-end type or the loop-end type. To change the blade, loosen the handle three or four turns, then press forward on the front end of the frame and insert the blade into the slots provided.

To make an internal cut, drill a 1/4 in. diameter hole in the waste stock, then stick the blade through the hole and attach it to the saw frame.

Hand Crosscut Saw - A hand crosscut saw is designed to cut ACROSS THE GRAIN on the PUSH STROKE. The front faces of its teeth have an angle of 15 deg. The back angle is 45 deg. See figure 5-3,left. BEVELING the edges of the teeth about 24 deg. gives them the appearance and cutting action of a series of knives.

The teeth are SET (bent to alternate sides) to make the cut or KERF wider than the thickness of the blade, figure 5-3, right.

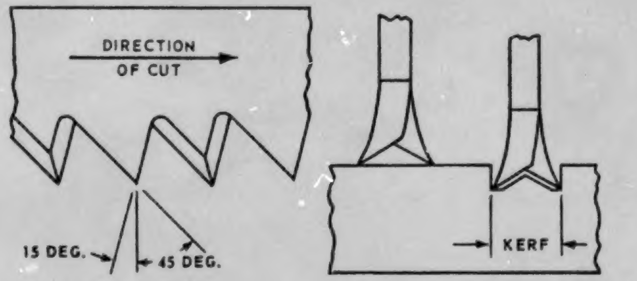


Fig. 5-3. Left. Crosscut saw teeth.
Right. Cross section of teeth.

Crosscut teeth score the wood, then the edges of the teeth form a groove and clear the sawdust from the kerf.

Coarseness of a saw is designated by the number of teeth per inch. For example, a saw with 8 teeth per inch is an 8-point saw.

To cross cut, first draw a square line across the end of the board with a try square and pencil. Hold the board firmly against a sawhorse or clamp it in a vise. Start the cut with a series of short strokes, the saw teeth being placed on the outside of the line. Use your thumb placed about two inches above the teeth as a guide. When the saw begins to cut, move your thumb away from the blade and make longer strokes with the saw held at an angle of about 45 deg. Gradually lengthen the strokes using light, uniform pressure. If the saw moves away from the line, twist the handle slightly as you continue sawing to bring it back to the line. As you end the cut, slow and lighten the strokes to prevent splitting, figure 5-4.

Hand Ripsaw - This saw is designed to cut WITH THE GRAIN and cuts on the push stroke. The front faces of its teeth have an angle of 8 deg. The back angle is 52 deg. The ripsaw teeth are filed straight across giving them the appearance and cutting action similar to a series of vertical chisels. The saw teeth are set evenly to about 1/3 the thickness of the blade so the kerf made by the saw gives clearance. A 5 point (5 teeth per inch) ripsaw works well for general purpose, figure 5-5.

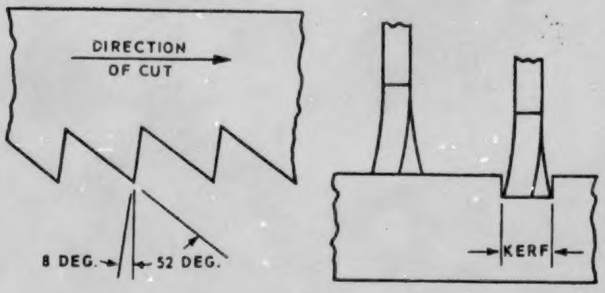


Fig. 5-5. Left. Ripsaw teeth. Right. Cross section of teeth.

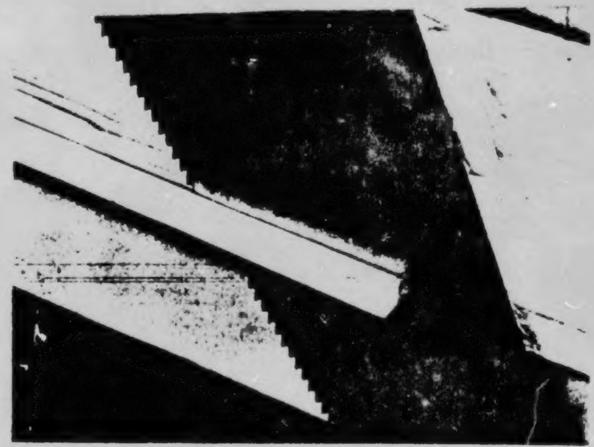


Fig. 5-6. Sawing with a ripsaw.

To rip, first lay out a straight line along the grain of the board with a square, straight-edge or chalk line. Hold the board firmly against a sawhorse or clamp it in a vise. Hold the ripsaw at an angle of about 60 deg. and saw as with crosscutting, figure 5-6.

Backsaw - a backsaw is used to make fine, accurate cuts as in making wood joints and finish cuts. Its teeth are small; 12 or more points per inch. The blade is thin for narrow kerfs and its back is heavy, hence its name.

To make a finish cut, mark a layout line, figure 5-7. As a guide you may clamp a straight board along the line. Use a scrap board beneath to protect your bench top. Keep the blade against the guide as you make slow, light strokes. See figure 5-8.

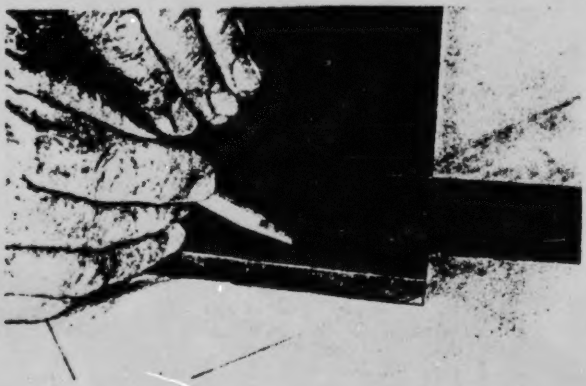


Fig. 5-7. Marking a square line at the end of a board.

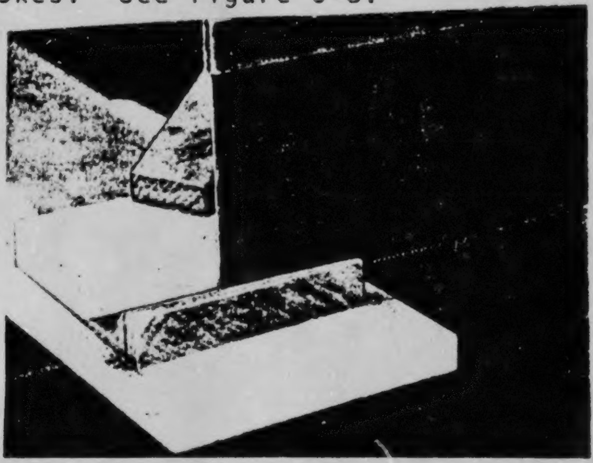


Fig. 5-8. Making a finish saw cut with a backsaw and a fixture.

Miter Box Saw - This device is equipped with a special backsaw and cuts angles from 45 to 90 deg. It is especially useful for jobs such as cutting molding, picture frames, etc. See figure 5-9.

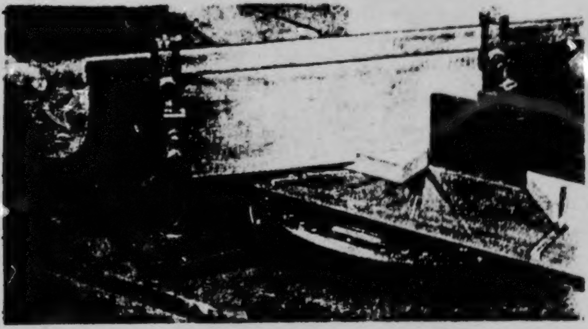


Fig. 5-9. Cutting a miter with a miter box saw.

Jig Saw - The power driven jig saw (scrollsaw) cuts like a coping saw and is primarily designed for curved cuts with thin stock (1 in. or less in thickness). Its size is determined by the distance from the blade to the overarm. A 24 in. jig saw is a popular size and will cut stock this wide. The blade moves up and down, cutting on the DOWNWARD stroke. The motor pulls the blade down and a tension spring in upper sleeve brings the blade up, figure 5-10.

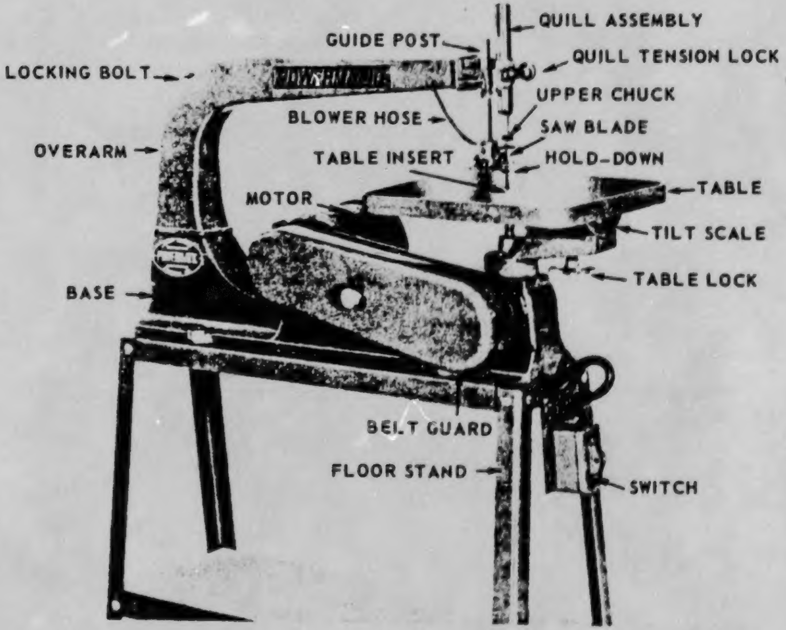
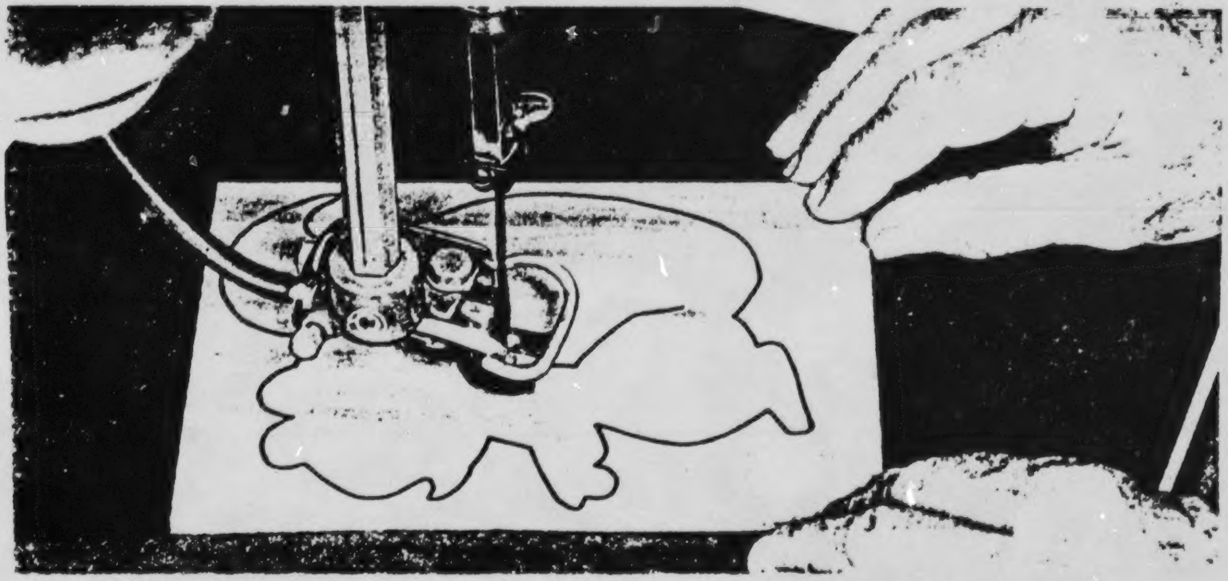

QUILL ASSEMBLY
GUIDE POST
QUILL TENSION LOCK
LOCKING BOLT
UPPER CHUCK
BLOWER HOSE
SAW BLADE
OVERARM
TABLE INSERT
HOLD-DOWN
MOTOR
TABLE
TILT SCALE
TABLE LOCK
BASE
BELT GUARD
FLOOR STAND
SWITCH

Fig. 5-10. Parts of a jig saw (scroll saw).

Sawing an Internal Cut - Drill a 1/4 in. hole in the waste stock near the line. Loosen the guide post and adjust the hold-down spring to press the stock lightly against the table. Turn the machine by hand to the bottom of the stroke. Place the blade, teeth pointing downward, through the hole into the lower chuck and tighten the thumbscrew. Pull the upper chuck down over the top of the blade and tighten the thumbscrew. Turn the machine by hand to check the adjustments. The blade should be straight vertically, the back of the blade being near the roller support in the guide assembly. As you saw, guide the work with both hands pushing forward just fast enough to keep the saw cutting, figure 5-11. Bypass sharp bends that you can complete later to help prevent breaking the blade.

Fig. 5-11. Sawing an internal cut with a jig saw.



Blades for the jig saw are usually 5 or 6 in. long but vary in size and teeth per inch. They are available to cut wood, metal, plastic and other materials. Manufacturer's catalogs supply information on blade selection. Most work can be done with a blade 0.110 in. wide, 0.020 in. thick and with 15 teeth per inch.

Safety and Care

1. Unplug the saw before making adjustments.
2. Keep your fingers from in front of the saw blade at all times.
3. Turn the saw by hand before turning on the power.
4. Push the stock forward rather than toward the sides.

Portable Jig Saw - This machine, also called a SABER SAW, is designed to be moved around over the work. The blade is heavier than in the table model jig saw and makes a rougher cut. It cuts through 3/4 in. stock with ease. The saber saw is especially useful where curves need to be cut in long stock, figure 5-12.

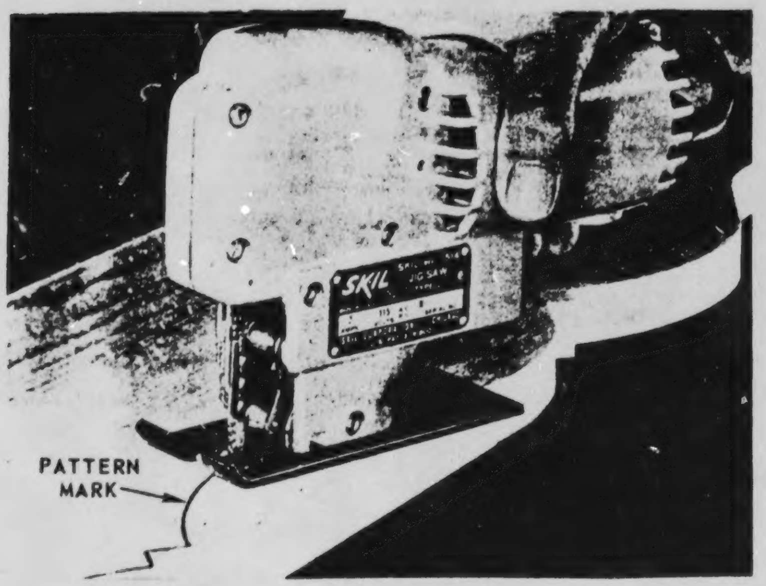


Fig. 5-12. Sawing curved cuts with a portable jig saw (saber saw). (Skil Corp.)

Bandsaw - The bandsaw serves a wide variety of uses. You can make straight and curved cuts, freehand or with a guide. You can cut wood, plastic and metal. The blade of this saw is a continuous band which revolves on two wheels. The size of a bandsaw is determined by the diameter of the band wheels. The upper wheel is adjustable up and down to tighten or loosen the blade. It can be tilted forward and back to adjust tracking of the blade to the middle of the wheel. A 14 in. bandsaw is a popular size, figure 5-13.

Blades are available in widths of 1/8 - 1/2 in. and in a variety of tooth sizes and styles. The total length is specified by the manufacturer. A HOOK or SKIP tooth blade is recommended when cutting resinous woods or plastics. A 3/8 in. wide blade may be used to cut a curve with a minimum radius of 1 1/2 in.

Upper and lower guide assemblies need to be checked frequently. For correct adjustment, the blade guides should clear the balde about .003 in. (approx. thickness of note paper) and the roller supports (backing bearings) should clear the back of the blade about 1/32 in.

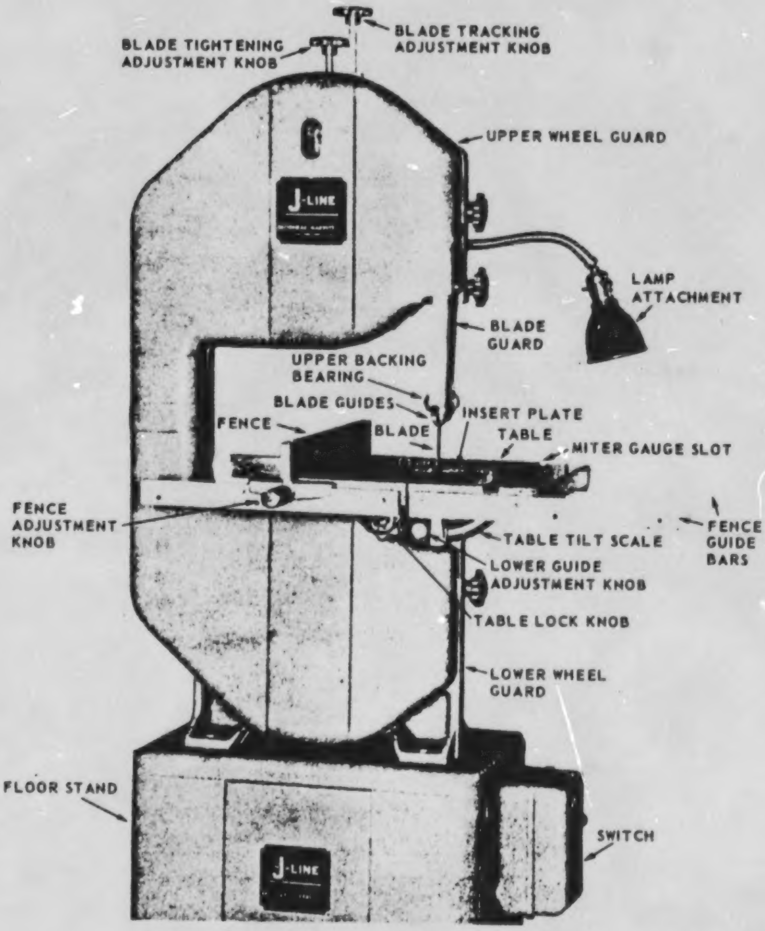

BLADE TIGHTENING ADJUSTMENT KNOB
BLADE TRACKING ADJUSTMENT KNOB
UPPER WHEEL GUARD
J-LINE
LAMP ATTACHMENT
BLADE GUARD
UPPER BACKING BEARING
BLADE GUIDES
FENCE
BLADE
INSERT PLATE
TABLE
MITER GAUGE SLOT
FENCE ADJUSTMENT KNOB
TABLE TILT SCALE
FENCE GUIDE BARS
LOWER GUIDE ADJUSTMENT KNOB
TABLE LOCK KNOB
LOWER WHEEL GUARD
FLOOR STAND
SWITCH
J-LINE

Fig. 5-13. Parts of a 14 in. bandsaw. (Brodhead–Garrett Co.)

Cutting with the Bandsaw - Lay out on the stock the cuts you plan to make and consider the sequence of the cuts to be made. SHORT cuts should be made first so that it is unnecessary to back out, figure 5-14. Straight cuts should be made before curved cuts for the same reason. Bypass sharp curves with longer curves and finish these cuts later. Sharp outside curves can be made by making several saw cuts perpendicular to the curve as RELIEF cuts, figure 5-15. Place stock on saw table and adjust guide post so that upper guide assembly is about 1/4 in. above work. As you cut, keep your hands to the sides, out of the direct line of the saw blade. Use only enough forward pressure to keep the blade cutting.

To rip narrow, straight stock (less than three inches wide) use a fence and a push stick, figure 5-16.

Safety and Care

1. Keep your hands to the side of the blade, away from its path.
2. Should the blade break, step aside and disconnect the machine.
3. Keep your fingers 2 in. or more from the blade at all times. Use a fixture to hold small pieces.
4. Always keep the upper guide assembly 1/4 - 1/2 in. from the stock.
5. To save the blade, push stock forward rather than toward the side.
6. Work within the capacity of the saw. A thick piece must be fed slower than a thin piece.

Circular Saw - The circular saw, often referred to as a TABLE saw, is one of the most productive machines you can use. By practicing a few precautions you can learn to use the circular saw safely and efficiently. The size of a circular saw is determined by the maximum diameter of the circular blade used. The blade revolves at high speed and a guard is kept over the blade for your protection. A movable fence is mounted on the table as a guide for ripping stock to width. A miter gauge is used as a guide for crosscutting and mitering, figure 5-17.

Commonly used circular saw blades are the CROSSCUT, RIP and COMBINATION. The crosscut blade has teeth sharpened and set similar to a hand crosscut saw which cuts like a series of KNIVES. The rip blade has teeth sharpened and set similar to a hand ripsaw which cuts like a series of CHISELS.

The plain combination blade has both crosscut and rip teeth and is used for ALL-PURPOSE work. Some combination blades are hollow ground (planer combination) making the blade thicker near the teeth. This provides for clearance of the blade in the saw kerf, eliminating the necessity of setting the teeth. A planer combination blade makes a smooth, accurate cut in crosscutting and mitering, however, blade clearance is usually insufficient for ripping.

SAFETY NOTE

Warp must be removed from the surfaces and at least one edge of boards to be cut with the circular saw.

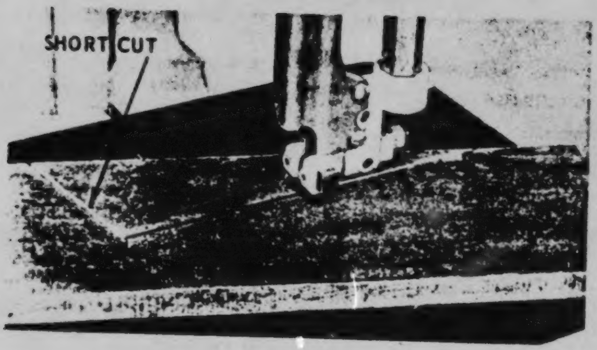


Fig. 5-14. Make the short cut first with a bandsaw.

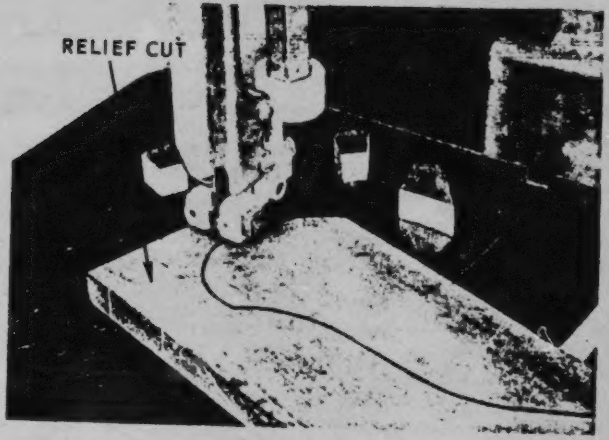


Fig. 5-15. Make relief (clearance) cuts before cutting around sharp curves with a bandsaw.

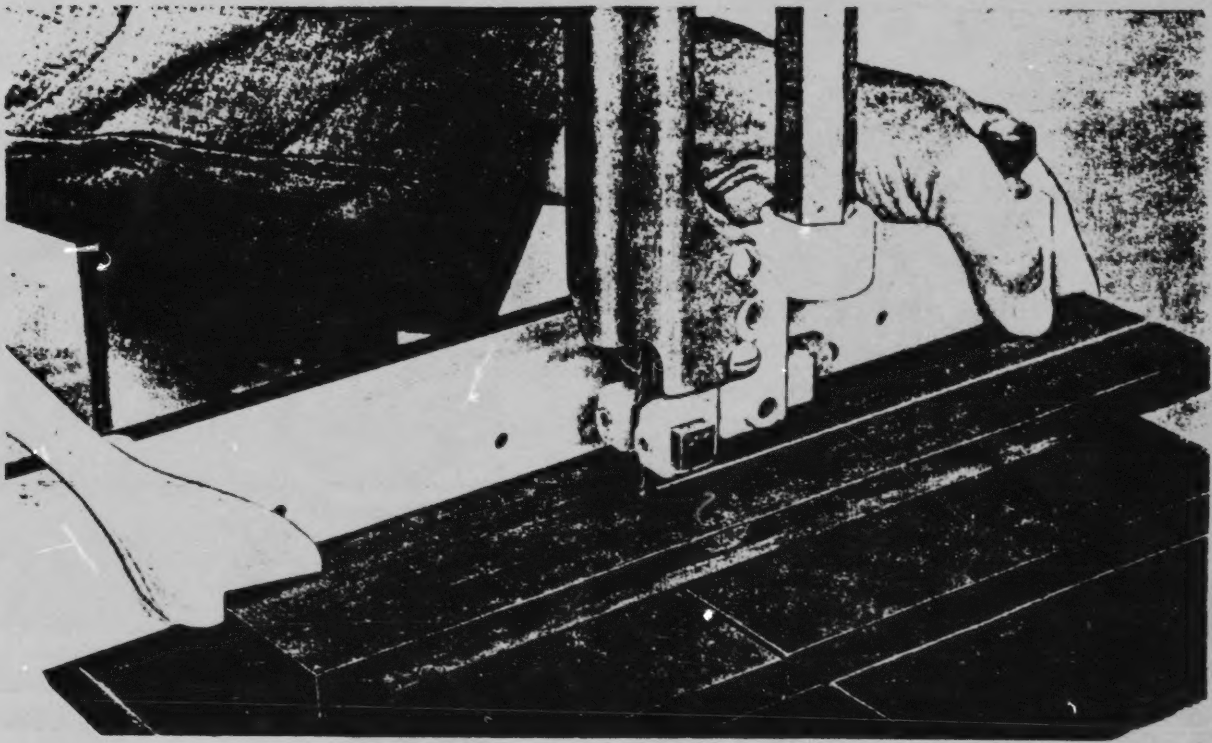


Fig. 5-16. Ripping narrow stock with a bandsaw and a push stick.

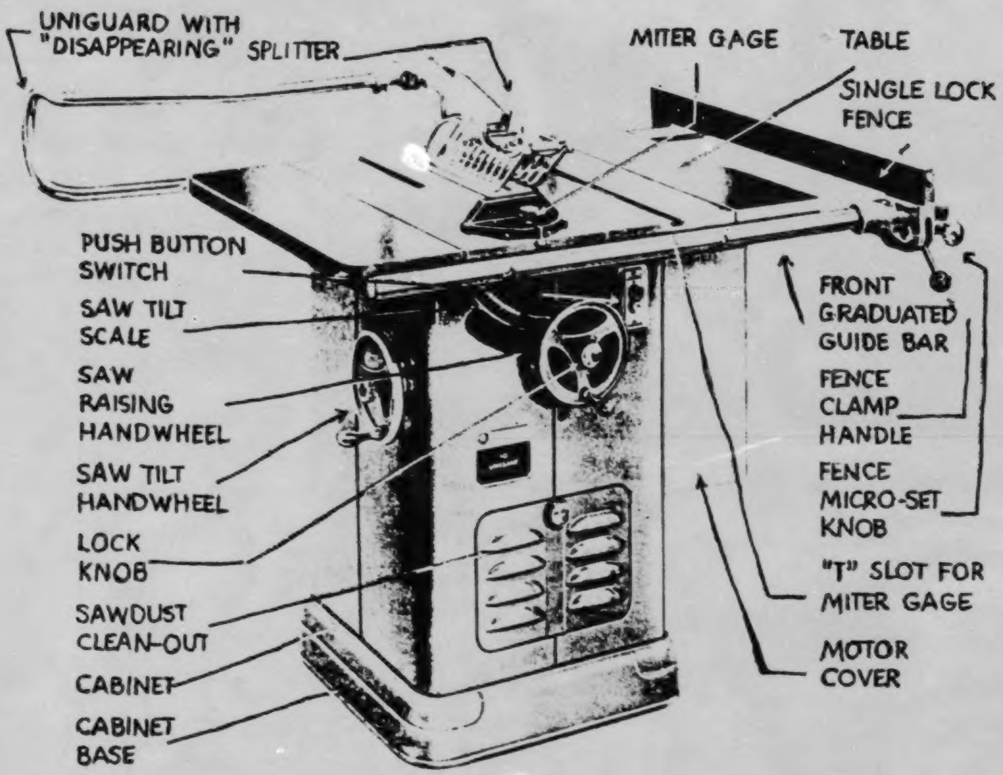

UNIGUARD WITH "DISAPPEARING" SPLITTER
MITER GAGE
TABLE
SINGLE LOCK FENCE
PUSH BUTTON SWITCH
SAW TILT SCALE
SAW RAISING HANDWHEEL
SAW TILT HANDWHEEL
LOCK KNOB
SAWDUST CLEAN-OUT
CABINET
CABINET BASE
FRONT GRADUATED GUIDE BAR
FENCE CLAMP HANDLE
FENCE MICRO-SET KNOB
"T" SLOT FOR MITER GAGE
MOTOR COVER

Fig. 5-17. Parts of a 10 in. tilting arbor circular saw.

Crosscutting - Make a mark on the board where you plan to make a cut. Raise the blade so it projects 1/8 in. above the stock. Lay the board on the table with the true edge against the miter gauge. Align the mark with the saw blade and place the guard over it. Move the fence out of the way (if the board is already square you can clamp a clearance block on the fence and use this block as a gauge for cutting several pieces to the same length). Stand slightly to one side of the blade and turn on the machine. Hold the stock firmly against the miter gauge as you push the gauge slowly along the groove, feeding the stock into the saw. Push the board past the saw blade and turn off the saw. See figure 5-18.

SAFETY NOTE

Wait until the saw stops before you pick up the piece sawed off.

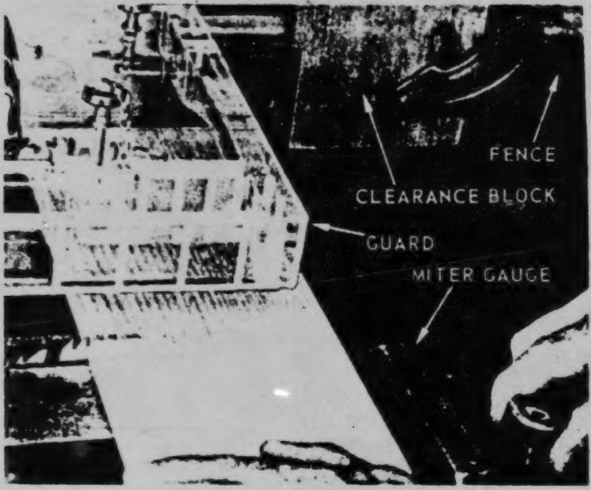

FENCE
CLEARANCE BLOCK
GUARD
MITER GAUGE

Fig. 5-18. Crosscutting duplicate pieces using a circular saw and clearance block.

Mitering - To saw a miter, set the miter gauge to theangle you desire to cut and proceed as with crosscutting, figure 5-19.

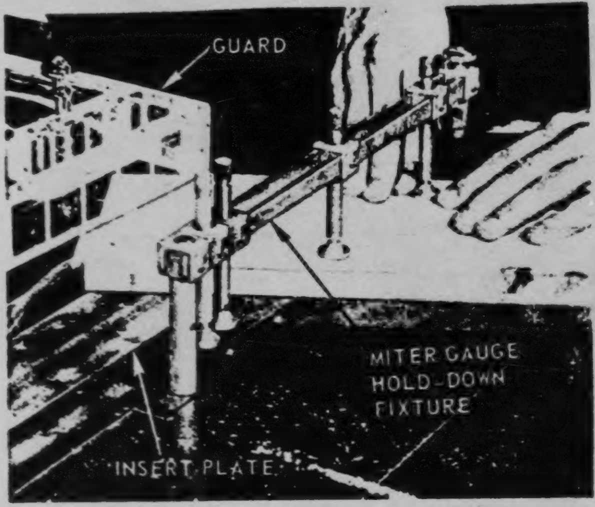

GUARD
MITER GAUGE
HOLD-DOWN
FIXTURE
INSERT PLATE

Fig. 5-19. Making a miter cut with a circular saw and a fixture.

SAFETY NOTE

For greater safety and accuracy in cutting miters, it is best to use a clamping device with the miter gauge. You can do this by setting the points of two flat head screws through a true-board and then attaching the board to the miter gauge as an auxiliary fence. The screw points act as anchor points to prevent the board from slipping as you make the cut. Another method is to use a miter gauge with a hold-down attachment as a fixture, figure 5-19.

Changing the Blade - Disconnect the power to the saw and remove the insert plate (the plate around the saw blade). Place a wrench on the arbor nut with one hand and wedge a board under the saw blade with the other hand. Turn the nut clockwise for removal (most saw arbors have left-hand threads). Remove the nut, collar and saw blade. Replace the desired saw blade by reversing this procedure. Be sure the saw teeth are mounted to cut TOWARD the stock when in operation, figure 5-18.

Ripping - Store the miter gauge so that it is protected from damage. Raise the blade 1/8 in. above the stock as in cross-cutting. Set the fence by using the scale on the front guide bar. You may want to check this distance by measuring between the fence and the nearest tooth point. Place the guard over the blade. Lay the board flat on the table with the straight-edge next to the fence. Turn on the saw and push the board slowly into the blade. Keep forward pressure only on the piece between the blade and the fence. For pieces narrower than four inches, use a push stick. Continue pushing the board until its entire length is cut and turn off the saw. WAIT UNTIL THE BLADE STOPS BEFORE YOU REMOVE PIECES OF WOOD FROM THE BLADE. See figures 5-17 and 5-20.

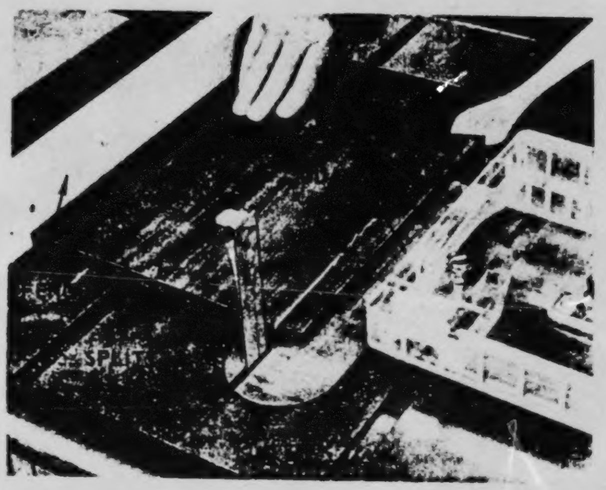


Fig. 5-20. Ripping a board to width with a circular saw. (Guard is removed to view the operation.)

SAFETY NOTE

Be sure to use the SPLITTER (sometimes called SLITTER) for ripping operations. The splitter, indicated by an arrow in figure 5-20, acts as a metal wedge in the saw kerf, separating the two pieces cut with the rip saw blade to help prevent binding. The splitter is also equipped with metal fingers which hold the board down as it is cut, serving as an antikickback device.

Beveling

A bevel is an angle cut along an edge of a board. To saw a bevel, turn the saw tilt hand wheel to the correct angle and proceed as in crosscutting or ripping. On many circular saws, each turn of the tilt hand wheel moves the arbor 2 1/2 deg. You can set the saw blade to the angle you wish to cut by using the indicator on the saw tilt scale, figure 5-17.

SAFETY NOTE

Be sure the waste stock will fall free at the end of the cut to help prevent kickback.

Radial Circular Saw

Although this saw is quite versatile, it is used mostly to cut boards to length. It is sometimes called a CUT-OFF saw. Stock to be cut to length is laid flat with a straight or concave edge against the fence. The saw is then pulled across the stock along the arm track.

SAFETY AND CARE

1. Check the setup before you turn on the saw.
2. Stand slightly to one side and keep your hands out of the path of the blade at all times.
3. Watch for others. See that no one stands in the path of the saw blade.
4. Cut only stock 1 foot or more in length. Use a hand saw for small pieces.
5. Use the correct blade and fence for the cut being made.
6. Always use a sharp saw blade and a saw guard.

METAL FASTENERS

Metal fasteners for woodwork include nails, screws, staples, bolts, splines, and many special items. Fasteners are used in nearly every type and kind of construction. Nails and screws are still the most common. However, in industrial production where the work is done with power drivers, staples and patented fasteners are used extensively.

Nails

One of the easiest ways to fasten wood together is with nails. Nailed joints are not as attractive or strong as those that are glued, but they are practical for packing boxes, crates, house faaming, or in finish work where they will provide sufficient strength and the nail heads can be covered.

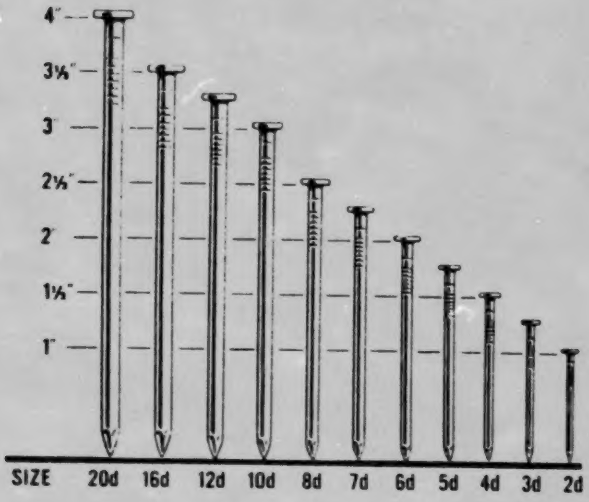


Fig. 8-4. Nail sizes. (United States Steel)

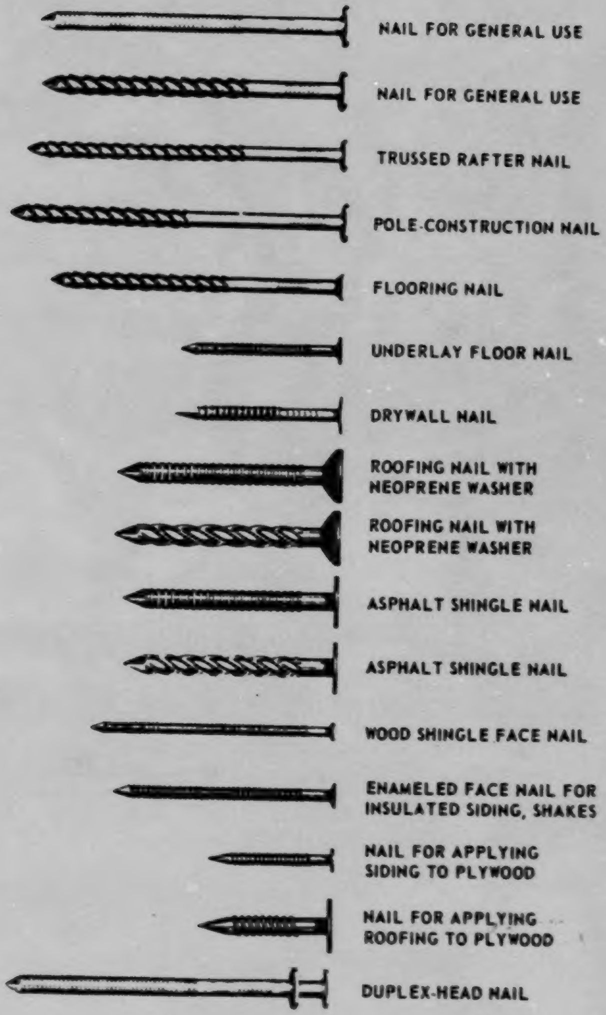

NAIL FOR GENERAL USE
NAIL FOR GENERAL USE
TRUSSED RAFTER NAIL
POLE-CONSTRUCTION NAIL
FLOORING NAIL
UNDERLAY FLOOR NAIL
DRYWALL NAIL
ROOFING NAIL WITH NEOPRENE WASHER
ROOFING NAIL WITH NEOPRENE WASHER
ASPHALT SHINGLE NAIL
ASPHALT SHINGLE NAIL
WOOD SHINGLE FACE NAIL
ENAMELED FACE NAIL FOR INSULATED SIDING, SHAKES
NAIL FOR APPLYING SIDING TO PLYWOOD
NAIL FOR APPLYING ROOFING TO PLYWOOD
DUPLEX-HEAD NAIL

Fig. 8-5. Annular or spiral threads on nails designed for special purposes. (Independent Nail and Packing Co.)

Driving Nails

Select an appropriate size hammer: a light one for light work and a heavier one for heavy work. Choose the nail with the smallest diameter that will provide the necessary holding power. On precise work, you may need to lay out the nailing pattern or mark the position of the bottom member so that you can easily locate the proper position for each nail. Always nail through the thin piece into the thicker piece. When possible; drive the nails into cross grain rather than end grain so they will have maximum holding power.

Grip the hammer well back on the handle and use a wrist movement to start the nail as shown in figure 8-6. Now move the hand that held the nail well out of the way and use a full swing (arm and wrist) to get power in the stroke. Keep your eyes firmly fixed on the nail head, just like you do when hitting a baseball or tennis ball. Ease up on the power of your strokes when the head gets close to the surface of the wood and stop when the head is flush. Try to avoid denting the wood with marks from the hammer. If the nail begins to bend it is best to remove it and start with a new one.

Nails are easy to drive in soft wood, but are difficult to drive in hard wood. When driving nails in hard wood a little wax or soap on the point will help. Be sure to keep the face of the hammer clean. For wood that is real hard, it is best to drill a pilot hole for the nail. When nailing at the end of a board, space the nail in from the end as far as possible while still retaining a good hold on the other member. Stagger the nailing pattern, figure 8-7, and avoid placing two nails close together along the same grain line. When there is danger of splitting the wood, blunt the sharp point of the nail with a hammer or cut it off with nippers. When the nail is slightly long for the work or you want to increase the holding power, drive it at an angle. In toenailing, figure 8-8, select the position and angle carefully, and stagger the nails so they will not intersect.

When driving casing nails or finish nails, leave the head slightly above the surface and then use a nail set slightly smaller than the nail head to bring the head flush with the surface or about 1/16 in. below. See figure 8-9. The size of the nail set is determined by the size of its tip. Sizes range from 1/32 to 5/32 in. by thirty-seconds. Using a brad pusher or driver is shown in figure 8-10.

Figure 8-11 shows correct procedures in pulling a nail. Force the claw under the nail head and start the removal. On some work you should protect the surface with a putty knife (as shown) or scraper blade. After the nail is withdrawn part way, use a block of wood under the head to protect the surface of the work and increase the leverage.

CAUTION

Use care when driving nails so that the hammer does not strike the surface of the wood. Hammer marks indicate the job was done by an amateur.

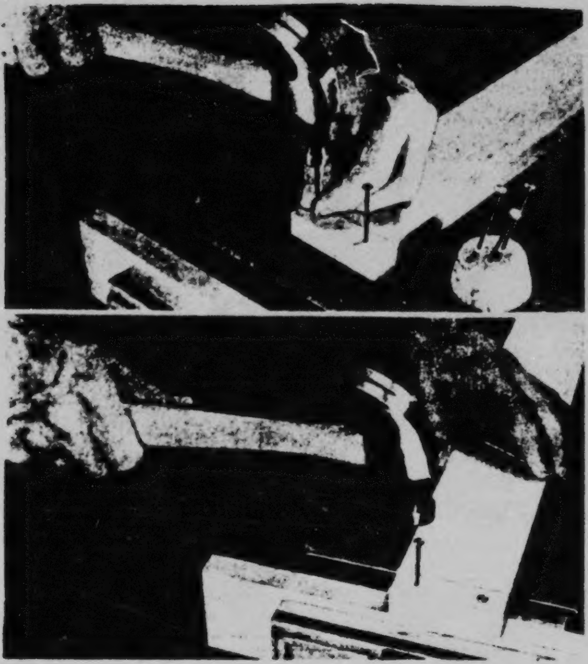


Fig. 8-6. Above. Starting nail with light strokes. Below. Driving nail with wrist and arm movement.

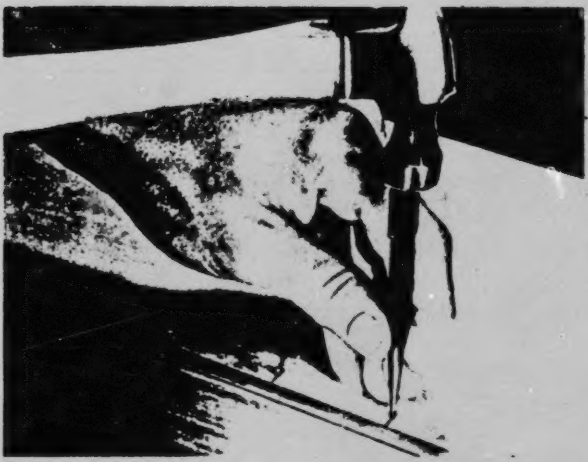
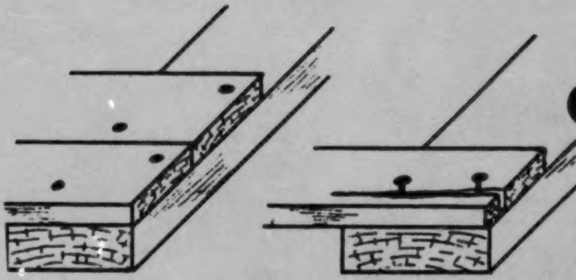


Fig. 8-9. Setting a nail.



GOOD NAILING PATTERN

NAILS DRIVEN IN LINE MAY SPLIT STOCK

Fig. 8-7. Use a good nailing pattern.

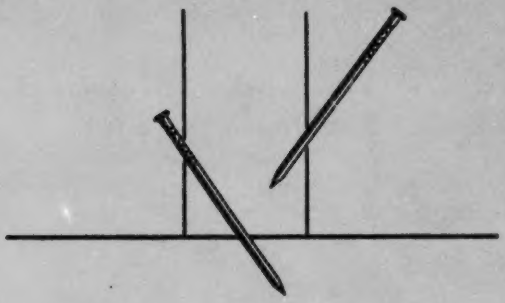
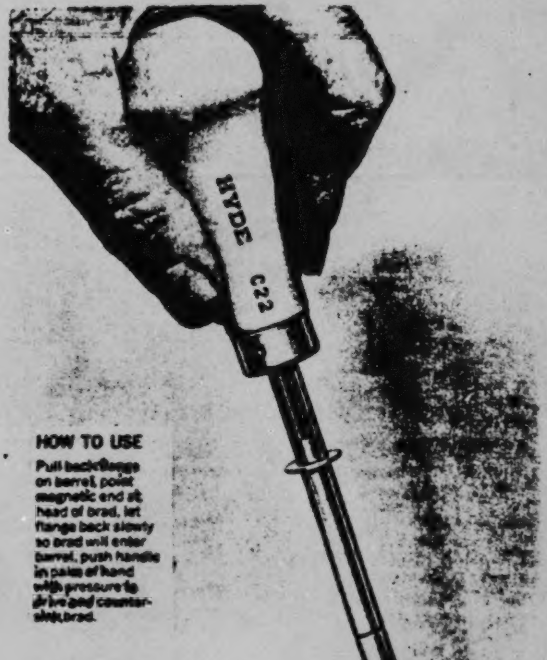


Fig. 8-8. Toenailing.



HOW TO USE

Pull back flange on barrel, point magnetic end at head of brad, let flange back slowly so brad will enter barrel, push handle in palm of hand with pressure to drive and countersink brad.

Fig. 8-10. Brad pusher or driver. (Hyde Tools)

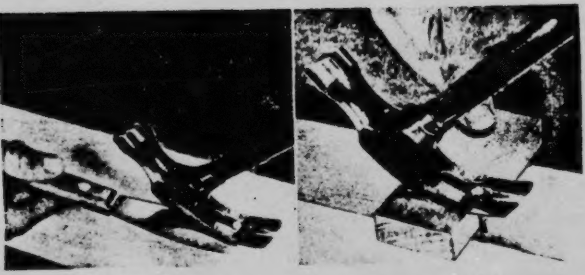


Fig. 8-11. Pulling a nail. Left. Using a putty knife to protect the surface. Right. Using a block of wood to protect the surface and increase leverage.

Wood Screws

Screws provide greater holding power than nails and offer the further advantage of easy disassembly and reassembly of parts. They require more time to install for which reason they are used chiefly in high grade cabinetwork and furniture construction.

Wood screw size is determined by the length and diameter (gauge number). Screws are classified according to the shape of head, surface finish, and the material from which they are made. See figures 8-12 and 8-13. Wood screws are available in lengths from 1/4 to 6 in. and in gauge numbers from 0 to 24. The gauge number can vary for a given length of screw. For example a 3/4 in. screw is available in gauge numbers of 4 through 12. The No. 4 would be a thin screw while the No. 12 would have a large diameter. From one gauge number to the next the size of the wood screw changes by 13 thousandths (.013) of an inch.

Most wood screws are made of mild steel with no special surface finish. They are usually concealed in the cabinet or furniture structure. Such screws are labeled as F.H.B., which stands for flat head bright. When screws will be visible, in high quality work, they should be nickel or chromium plated or made of brass. The heads should be round or oval. Wood screws are priced and sold by the box which contains one hundred (100). To completely specify wood screws they would be listed like this:

10 - 1-1/2 x No. 10 - Oval Head - Nickel.

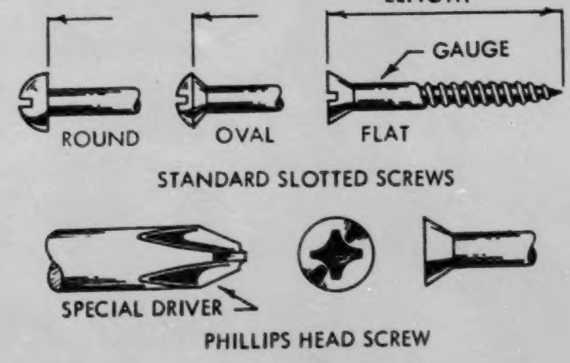


Fig. 8-12. Kinds of wood screws.

	0	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20
DIAMETER DIMENSIONS IN INCHES AT BODY	.060	.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.203	.216	.242	.268	.294	.320
TWIST BIT SIZES *For Round, Flat and Oval Head Screws in Drilling Shank and Pilot Holes.*																	
SHANK HOLE HARD & SOFT WOOD	1/16	5/64	3/32	7/64	7/64	1/8	9/64	5/32	11/64	3/16	3/16	13/64	7/32	1/4	17/64	19/64	21/64
PILOT HOLE SOFT WOOD	1/64	1/32	1/32	3/64	3/64	1/16	1/16	1/16	5/64	5/64	3/32	3/32	7/64	7/64	9/64	9/64	11/64
PILOT HOLE HARD WOOD	1/32	1/32	3/64	1/16	1/16	5/64	5/64	3/32	3/32	7/64	7/64	1/8	1/8	9/64	5/32	3/16	13/64
AUGER BIT SIZES FOR COUNTERSUNK HEADS			3	4	4	4	5	5	6	6	6	7	7	8	9	10	11

Fig. 8-13. Wood screw sizes.

Give careful consideration to the selection of the kind and size of screw that will be best suited for your work. To secure the maximum holding power the screw should enter the base piece of wood the entire length of the threads. This is about two-thirds of its length. This may not be possible in thin stock. Where the screw will be anchored in end grain you will need to use extra length since end grain does not hold screws well. It is good practice to use the smallest screw diameter that will provide the required holding power.

Drilling Holes for Wood Screws

When fastening wood with screws, two different size holes should be drilled. One should be the size of the screw shank, and the second a little smaller than the root diameter of the screw thread, figure 8-14.

Use good judgment in selecting the size of the drill bits. The size of the shank hold should be just large enough that the screw can be pushed in with the fingers. The size of the pilot hole (also called an anchor hole) for a given screw will vary depending on the hardness of the wood. For soft wood use a hole that is about equal to 70 percent of the root diameter and for hard wood about 90 percent. When working with hard wood, the pilot hole should be drilled almost as deep as the screw will go, while for soft wood it is drilled to about one-half of this depth. If you are using a large number of screws of equal size in an assembly, it will be worthwhile to experiment with scrap wood to determine just the right pilot hole for the size of screw and kind of wood you are using.

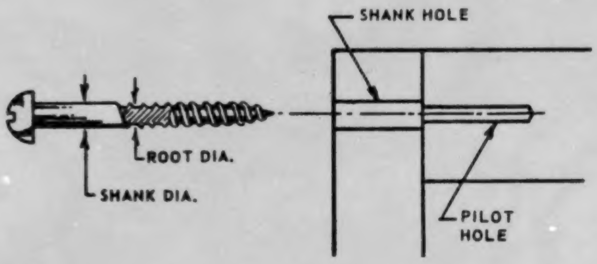


Fig. 8-14. Holes for wood screws.

Use center lines to mark the position of the screws. Make this layout carefully so the screws will be properly spaced, especially if the screw heads will be visible. Figure 8-15 shows a sequence of operations for drilling the holes. After the center of the screw hole is marked with a scratch awl, the shank hole is drilled. A countersink bit mounted in the brace is then used to countersink the hole to a size that will exactly match the screw head. The second piece of stock is then clamped in position and the pilot holes are drilled.

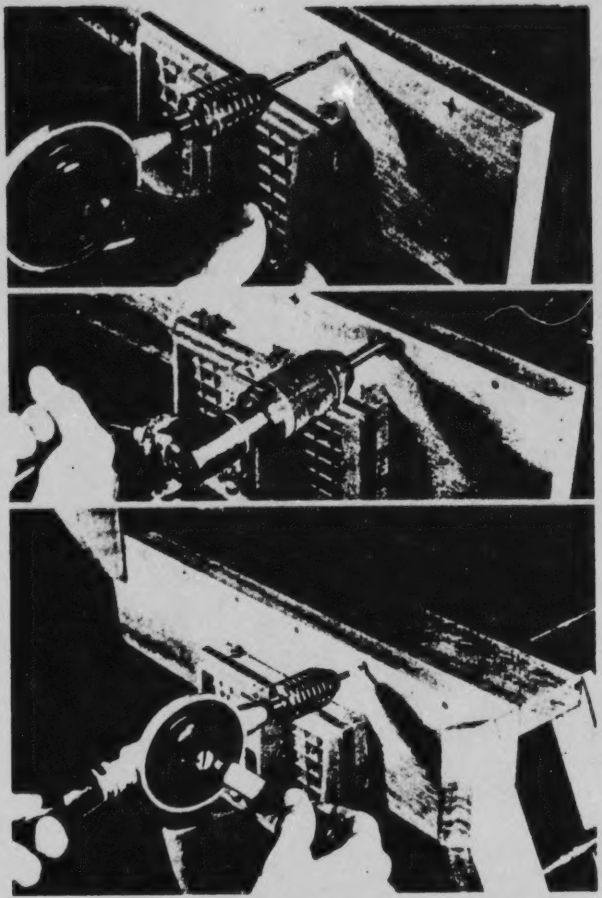


Fig. 8-15. Drilling holes for screws. Above. Shank hole. Center. Countersinking. Below. Pilot hole. Note masking tape wrapped around drill to mark hole depth.

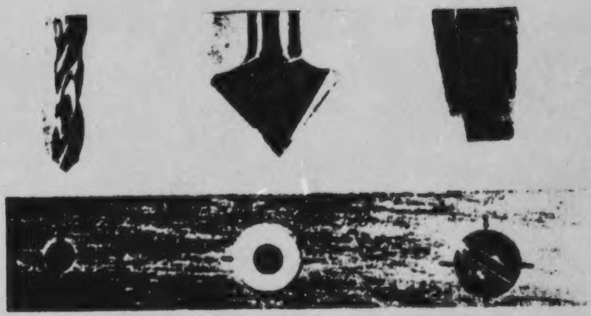


Fig. 8-16. Drilling and countersinking for a flat head screw.

Both flat and oval head screws need to be countersunk. Use care in doing the countersinking so the head will fit correctly as shown in figure 8-16. Flat headed screws look especially bad if not perfectly aligned with the surface. Your work may require that the screw head be recessed and the hole plugged. For this the shank hole will need to be counterbored. Remember to bore the large hole (size of the screw head) first and then drill the shank hole.

Setting Screws

The parts of a standard screwdriver are shown in figure 8-17. A number of sizes and styles are available. The size is specified by giving the length of the blade, measuring from the ferrule to the tip. The most common sizes for woodwork range from 1 1/2 to 6 inches.

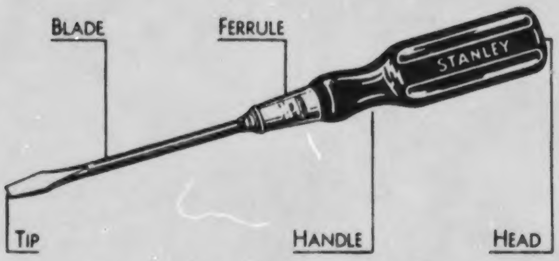


Fig. 8-17. Parts of a standard screwdriver.

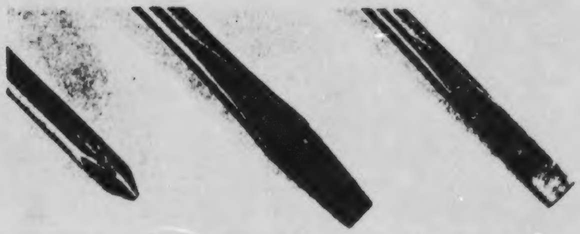


Fig. 8-18. Screwdriver tips. Left. Phillips. Center. Standard. Right. Cabinet.

The size of a Phillips screwdriver is given in a point size that ranges from a No. 0, the smallest, to a No. 4. Size numbers 1, 2 and 3 will fit most of the screws used in the school shop.

Tips of screwdrivers must be carefully shaped, and should look somewhat like those shown in figure 8-18. For a slotted screw they must be square, the correct width and fit snugly into the screw. The width of the tip should be equal to the length of the bottom of the screw slot. The sides of the screwdriver tip should be carefully ground to an included angle of not more than 8 deg. and to a thickness that will fit the screw slot. Use the side of the grinding wheel to form a flat surface. If the grinding is done across the sides, the tip will hold in the screw slot better. See figure 8-19.

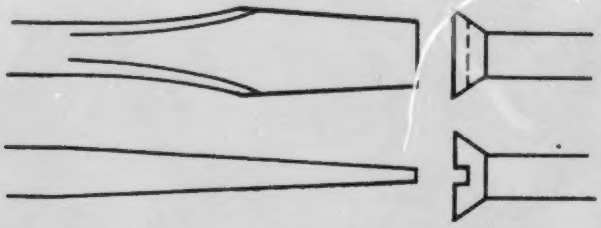


Fig. 8-19. The screwdriver must fit the screw.

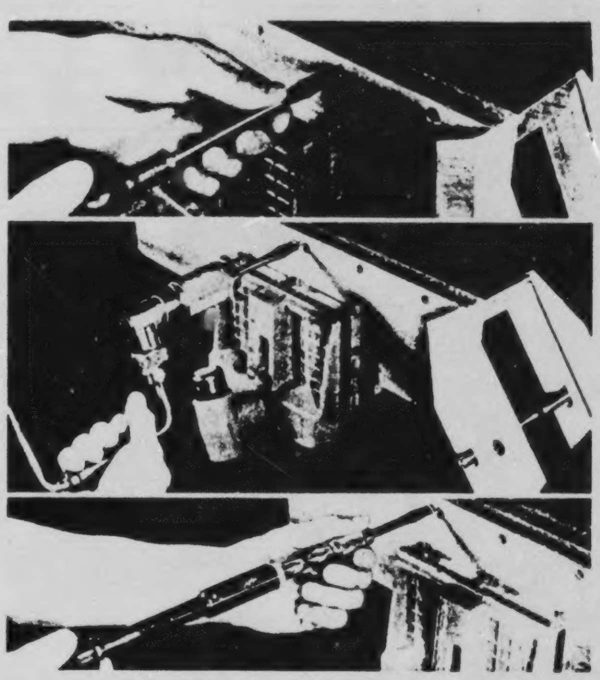


Fig. 8-20. Setting wood screws. Above. Screwdriver. Center. Screwdriver bit mounted in brace. Below. Spiral ratchet screwdriver.

If you have properly drilled holes for the screw, it is an easy matter to insert the screw in the shank hole and drive it "home" with the screwdriver, see figure 8-20. Use care that the screwdriver does not slip out of the slot and dent the surface of your work. Using Phillips type screws helps eliminate this problem because the tip cannot easily slip out of the screw slot. A screwdriver bit mounted in a brace is a good way to set large screws. The brace provides lots of leverage so be careful that you do not twist off the screw or damage the head. A spiral ratchet (automatic) screwdriver, will save time when you have a large number of screws to set.

A little wax or soap on the threads will make it easier to drive screws in hard wood. Do not apply too much force or the screw will twist off in the wood. They usually break just where the threads start, and the part embedded in the wood is very difficult to remove. If the screw turns too hard, it indicates that the holes were not properly drilled so you should remove the screw and make them larger.

CAUTION:
When setting screws, if you use too much force or a poorly shaped screwdriver tip, you will damage the slot in the screw heads and make your work appear shoddy.

Brass screws are much softer than steel screws and are easily twisted off or otherwise damaged. On very fine work it is often worthwhile to first drive a steel screw of the same size (this will cut the threads in the pilot hole), then remove it and set the brass screw.

When drilling holes for a large number of screws a great amount of time can be saved by using a special multi-operation bit like the one shown in figure 8-21. In a single stroke it will drill the pilot hole, shank hole, and either score the surface for countersinking or counterbore the work for recessing the screw head. Figure 8-22 shows a similar type of bit designed for drilling and countersinking being used in an electric drill. Drill bits of this kind are designed to match given sizes of screws. Bits are available for the commonly used screw sizes.

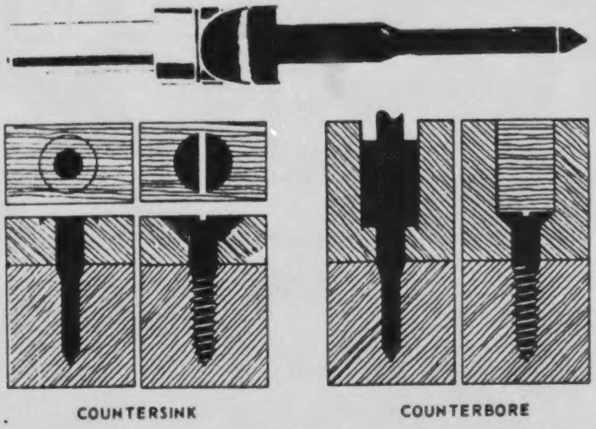


Fig. 8-21. Special bit for screw holes. (Stanley Tools)

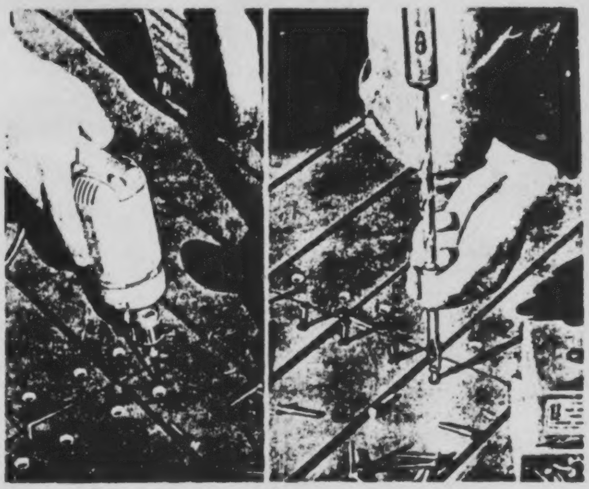


Fig. 8-22. Left. Drilling countersunk holes with special bit. Right. Setting screws with a spiral ratchet screwdriver.

Special Fasteners

Figure 8-23 shows a number of metal fasteners especially designed for woodwork. The hanger bolt has wood screw threads on one end and machine threads on the other. Lag screws and carriage bolts are often used for rough construction or for concealed work in cabinetmaking. Stove bolts are used frequently in metal work and are sometimes useful in joining certain parts in woodwork.

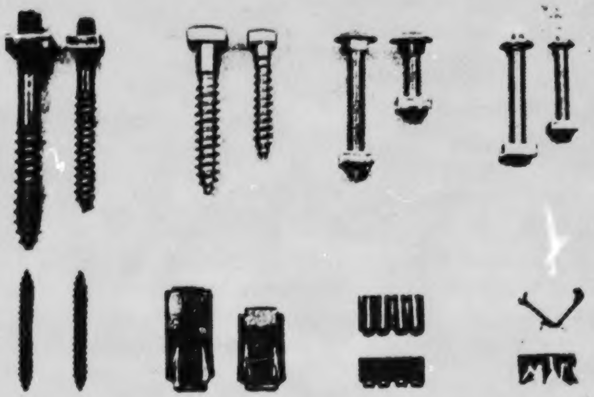


Fig. 8-23. Special fasteners. Top row. Hanger bolts, lag screws, carriage bolts, stove bolts. Bottom row. Dowel screws, splines, corrugated fasteners, chevrons.

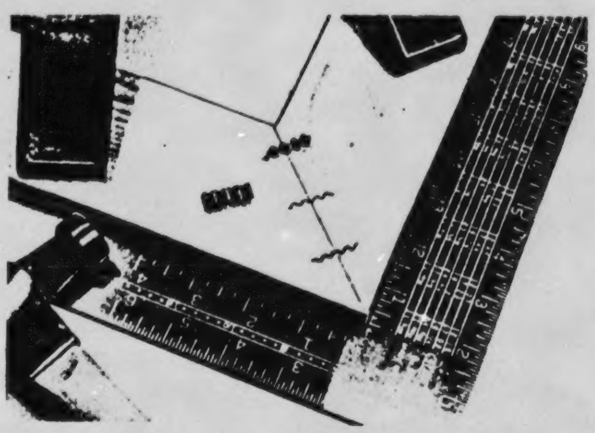


Fig. 8-24. Using corrugated fasteners to hold miter joint.

Corrugated fasteners are used for roughwork and can be quickly applied. They drive and hold best when set at an angle with the wood grain. For an installation like the one in figure 8-24, they should penetrate the wood about one-half of its thickness. Hold or clamp the parts in position and then drive the fastener into one side and then the other. The ones set in the opposite side should be staggered so they are not aligned with the ones on the face side. Corrugated fasteners are available in sizes of 1/4, to 3/4 in. They are packed in units of 100.

Steel splines can be driven into soft wood along the grain, but it is better to cut a saw kerf first. Clamp the stock together so you can cut into the edges or ends of both pieces at the same time. Use a backsaw or dovetail saw and cut to a depth equal to one-half of the spline width. Clamp or hold the pieces together and drive in the spline as shown in figure 8-25. The spline length should be about equal to the thickness of the stock. They are available in several sizes and are sold in lots of 100. Chevrons work in about the same way as splines but are designed especially for miter joints.

Dowel screws have wood screw threads on each end. If you set them in two pieces of the same kind of wood they will penetrate each piece an equal distance if you drill the holes exactly the same. To set only one end, clamp the other end between two hard wood blocks. Do not use pliers or you will damage the threads.

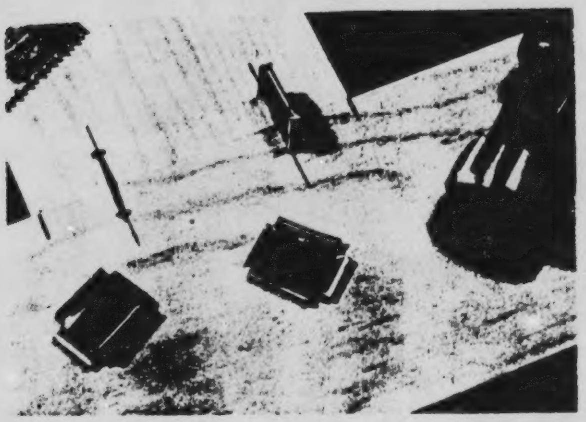


Fig. 8-25. Fastening a butt joint with steel splines.

Metal plates and angles, figure 8-26, can be used in many ways to assemble parts and reinforce wood joints. They are attached with screws and since they are unattractive they should be used in cabinetwork only where they can be concealed.

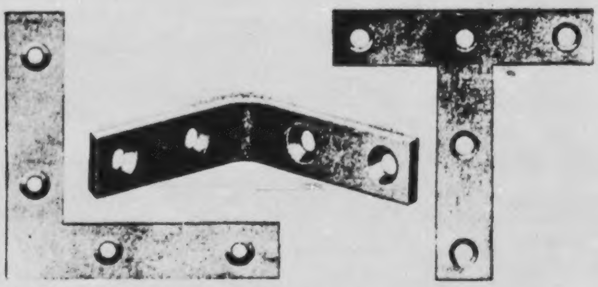


Fig. 8-26. Left. Flat corner plate. Center. Bent corner iron. Right. T-plate.

BORING AND DRILLING

Hand Tools

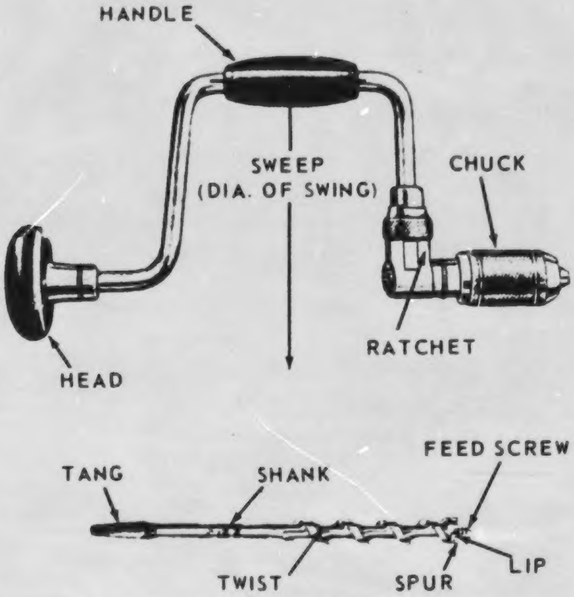
In woodworking, holes 1/4 in. and smaller are usually drilled with a hand or power drill. Holes larger than 1/4 in. are bored using an auger bit, expansion or forstner bit.

Brace

A brace is used to hold the bit and to provide leverage needed to turn the bit into the wood. A brace is also used with screwdirver bits to drive screws and with countersinks to provide recesses for screw heads. The brace is made to hold either round or square bit shanks. Its size is designated by the DIAMETER OF SWING (circle made by the brace handle when turned). A 12 in. brace is a common size. The brace is available with a RATCHET (a device for making part of a swing) for close work. See figure 6-1, above.

Auger Bits

Auger bits are used to bore holes in wood and other soft materials. They may be purchased in sizes ranging from 3/16 to 2 in. in diameter. The size of a bit is indicated by a number stamped on the tang which shows the diameter in sixteenths of an inch, figure 6-1, below.



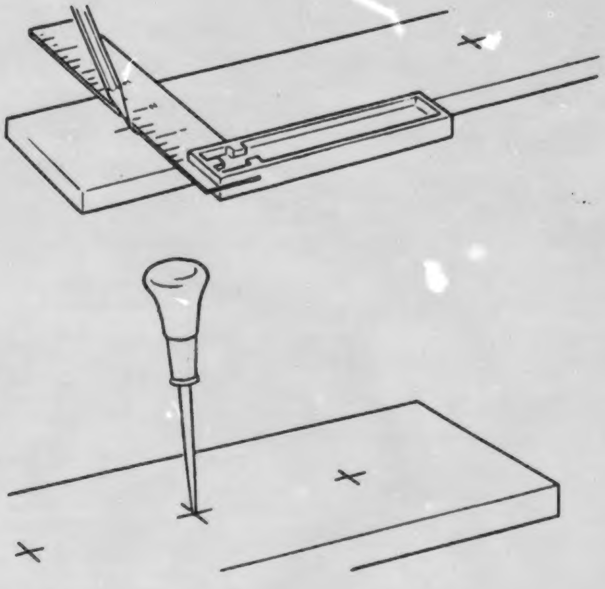


Fig. 6-1. Left. Above. Parts of a brace. Below. Parts of an auger. Fig. 6-2. Right. Above. Laying out holes. Below. Using awl to mark hole locations.

Boring Straight Holes

Lay out holes to be bored and mark the locations with an awl, figure 6-2. In boring, hold the bit straight (perpendicular) to the stock. Use only enough pressure to keep the bit cutting. Use a piece of scrap wood as a back-up board to assure a smooth hole when the bit cuts through the wood. See figure 6-3.

Another method is to bore a hole until the feed screw of the bit comes through the board, then complete the boring of the hole working from the other side.

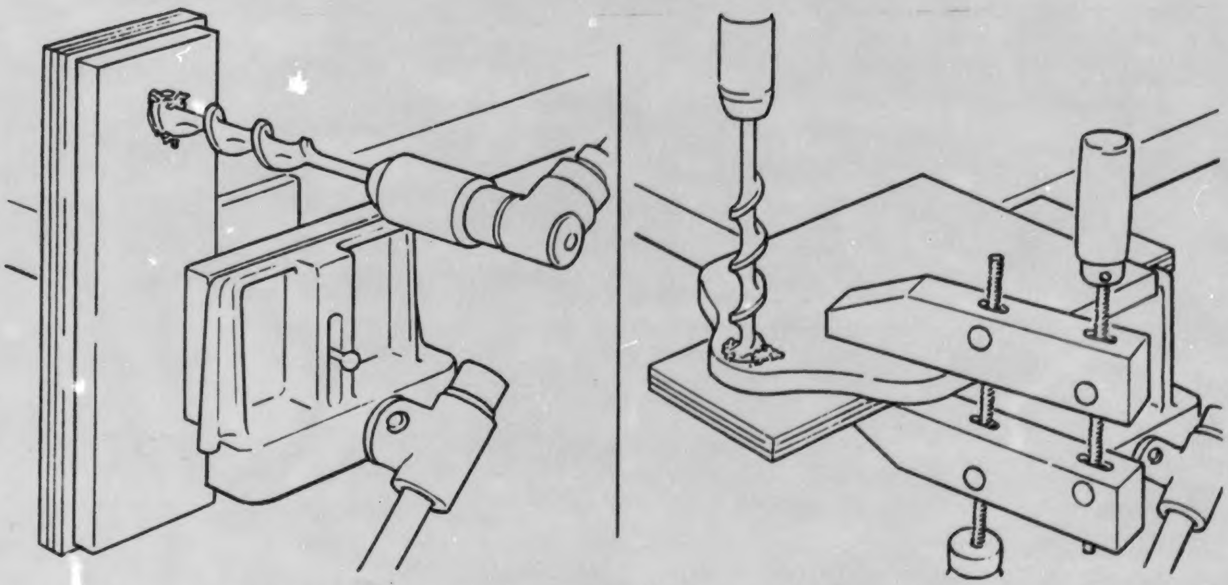


Fig. 6-3. Left. Boring a hole in a horizontal position with a brace and auger bit. Right. Boring a hole in a vertical position.

Boring Holes at an Angle

Lay out holes to be bored and mark the locations with an awl. A bevel gauge set at the proper angle may be used as a guide, figure 6-4.

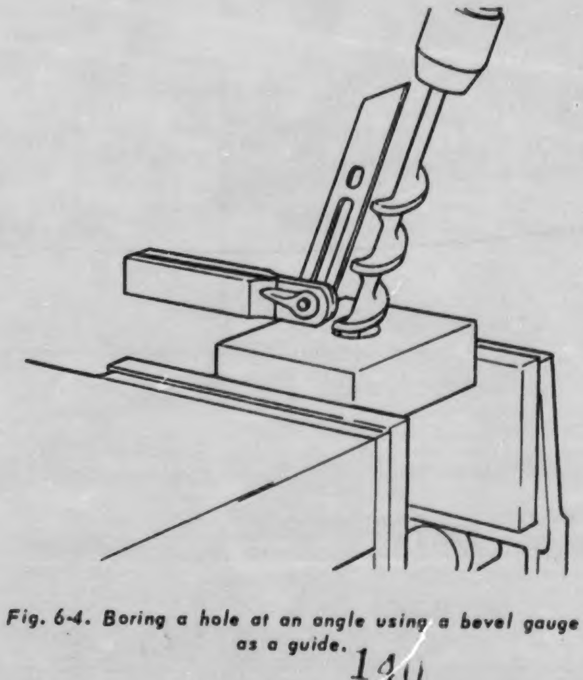


Fig. 6-4. Boring a hole at an angle using a bevel gauge as a guide.

Forstner Bit

A forstner bit which has no spurs, is designed to smooth bottoms of holes bored with other bits. To use this bit, hold the brace as with other auger bits, figure 6-5.

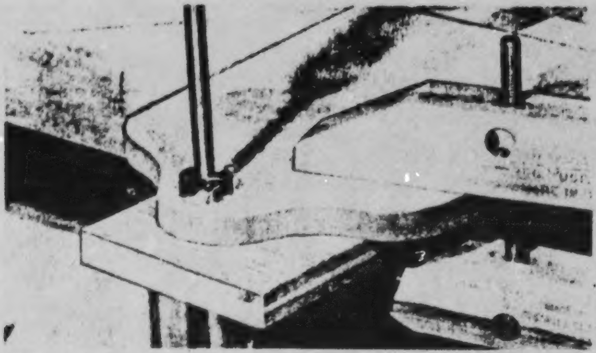


Fig. 6-5. Smoothing the bottom of a hole with forstner bit.

Expansive Bit

Large holes may be bored with expansive bits. This type bit is usually adjustable to bore holes from one to three inches in diameter. Set the expansive bit to the desired size and bore a trial-hole in a piece of scrap stock. Make minor adjustments if necessary, then bore the hole as with an auger bit, figure 6-6.

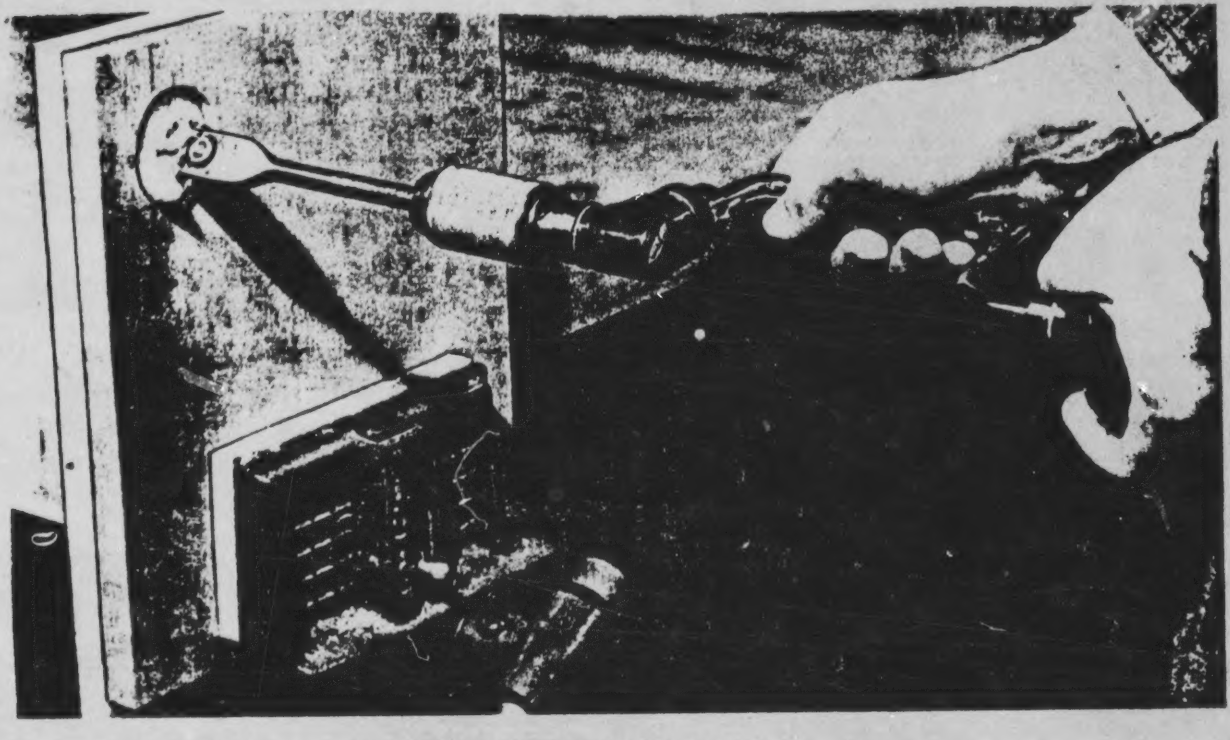


Fig. 6-6. Boring a hole with a brace and expansive bit.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

SHEET METAL

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

SHEET METAL

HAND TOOLS

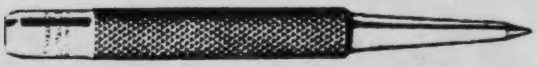
The hand tools discussed below are the more common hand tools used by the sheet metal worker and are the tools that you would use for most of your sheet metal projects.

A scratch awl - is used to mark lines on a sheet of metal in layout work. It is sometimes called a scriber.

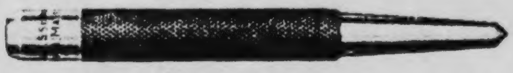
The prick punch - is used to make small indentations in metal for locating points for dividers and fold lines.

A center punch is used to make small indentations in doing layout work on the thicker sheets of metal such as 18 gage and thicker.

(A) Scratch awl. (Courtesy Whitney Metal Tool Company)



(B) Prick punch. (Courtesy The L.S. Starret Company)



(C) Center punch. (Courtesy The L.S. Starret Company)

Dividers - are used for making arcs and circles or dividing a line into equal parts and for spacing rivet holes.

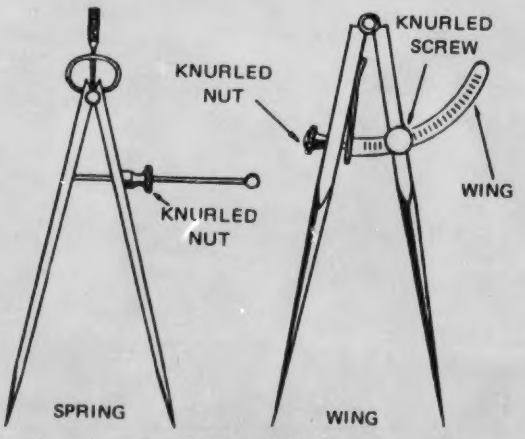
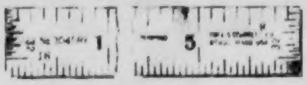
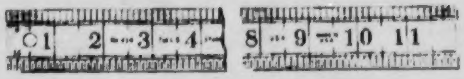


Fig. 2-2 Dividers.

Steel Rules are an absolute necessity in laying out sheet metal patterns. They can be purchased with 1/8, 1/16, 1/32, 1/64" graduations and with 1/10, 1/50 and 1/100" graduations. A steel rule with a 1/16 and 1/32" graduation is more convenient for most shop metal sheet metal projects. Steel rules with the 1/10 and 1/100 graduation are needed by precission sheet metal workers. A steel rule is required. Almost an absolute necessity for sheet metal work are the 6" steel rule, a 12" steel rule and the circumference rule. Sheet metal workers usually use steel rules for laying out a sheet metal pattern because the edges do not wear down and they retain their accuracy. The 6" steel rule shown below, is used for laying out the smaller sheet metal patterns while the 12" rule, also shown below, is used for laying out sheet metal patterns that require dimensions larger than 6". The circumference rule is used for laying out the larger sheet metal patterns and for finding the circumference of a circle. Most circumference rules are either 36" or 48" in length. The top edge is marked in 16th of an inch and the bottom edge converts the diameter of a circle to its circumference. The back side contains details helpful for some sheet metal workers.



(A) Six-inch steel rule. (Courtesy The L.S. Starrett Company)

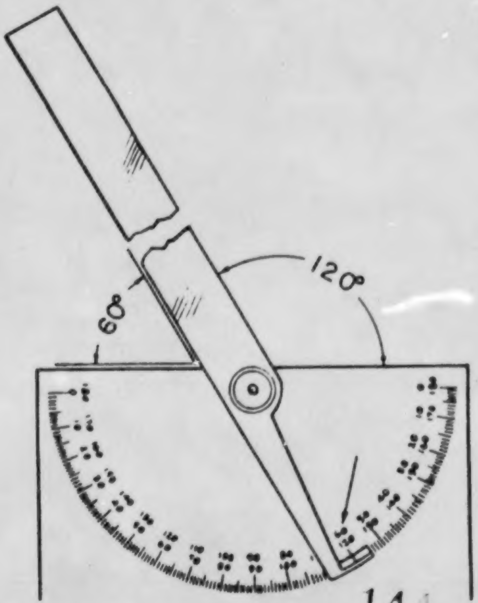


(B) Twelve-inch steel rule. (Courtesy The L.S. Starrett Company)

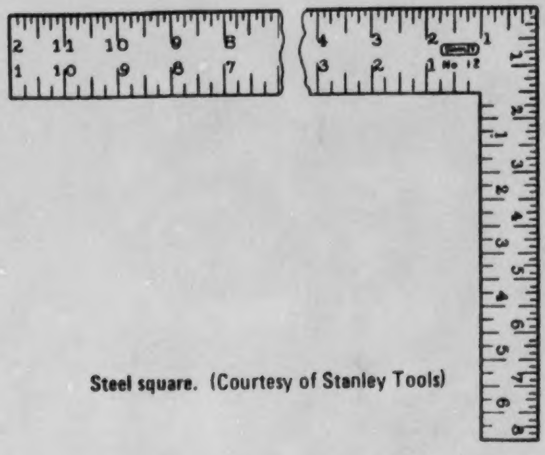
(C) Circumference rule. (Courtesy Niagara Machine & Tool Works)

1
2
3
4
CIRCUMFERENCE INCHES IN STEEL

A swinging blade protractor shown below is used to layout and measure angles on sheet metal patterns and to check angles on parts that have been formed or are being formed.

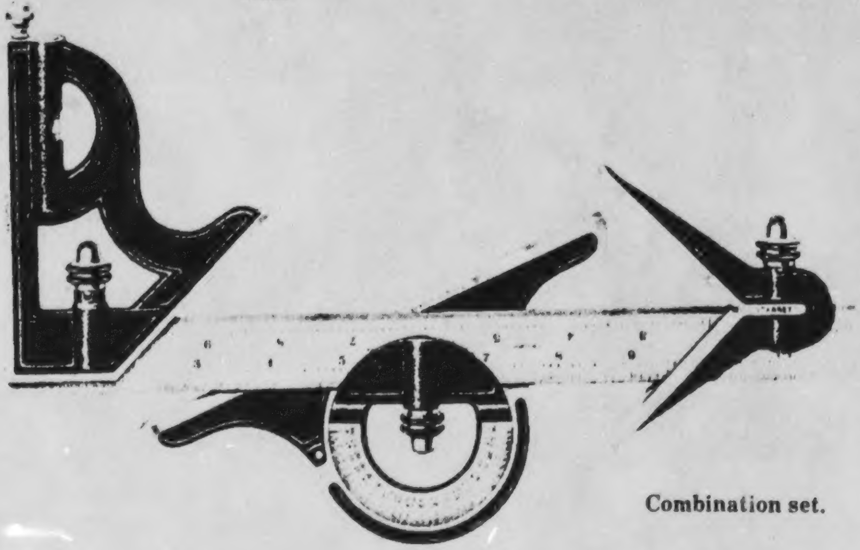


The common carpenter's square is used for squaring the corner of a sheet of metal and also for calculating pitch angles of roofs.



Steel square. (Courtesy of Stanley Tools)

The combination square shown below, is also used in layout work. It's sliding head makes it much easier to use than a common square. It is called the combination square because the head of the square can be removed from the rule and a protractor head can be inserted.

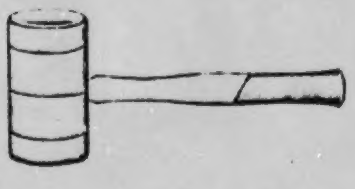


Combination set.

The riveting hammer has a slightly rounded face with beveled edges to prevent it from marring the metal. This hammer is used for riveting sheet metal and for pounding over Pittsburg seams. It is used more often than any other hammer in the sheet metal shop.

(A) Riveting hammer. (Courtesy Stanley Tools Div. of the Stanley Works)

A mallet is used for working with copper or aluminum. The head of the mallet is made from rawhide, wood, plastic or rubber to prevent marring the metal.



(B) Mallet. (Courtesy O.P. Link Handle Co.)

Combination snips are used to cut straight lines and to cut irregular lines with a relatively large arc or radius. These are the snips used most commonly by sheet metal workers because they can be used for many jobs for which special snips are not available.

(A) Combination snips.

Aviation snips are used to cut small curves and to cut straight 90° inside corners. They are also called airplane snips and are made in 3 styles; left hand, right hand and straight.

(B) Left-hand aviation snips.

(D) Right-hand aviation snips.

(C) Straight aviation snips.

The left hand aviation snips are used in cutting curves or angles toward the worker's left hand side. The right hand snips are used in cutting curves and angles toward the worker's right hand side. The straight aviation snips are used in cutting straight lines.

A hand punch is used to punch small holes in light weight sheets of metal upward to 18 gage material. It can punch holes ranging from 3/32' to 9/32' in diameter. Each punch is 1/32' larger than the next smaller punch. The hand punch can reach only as far from the edge of the metal as is the depth of its throat.

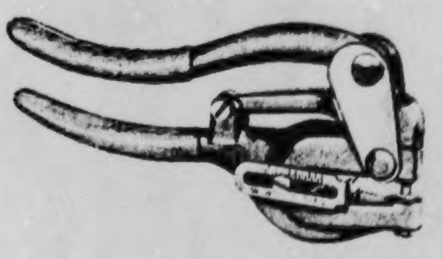
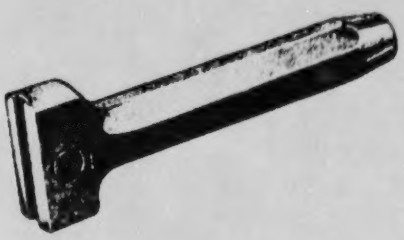


Fig. 4-6. Hand punch. (Courtesy Whitney Metal Tool Company)

A grooving tool is used with a hammer to form a grooved seam. The slot in the grooving tool fits over the lock of the seam.



(B) Grooving tool. (Courtesy Whitney Metal Tool Company)

Slip joint pliers are used for forming and gripping wire for completing a wired edge and with a screw driver in assemblying sheet metal parts with nuts and bolts.

(C) Slip-joint pliers. (Courtesy Vaco Products Co.)

A screw driver is used more often for purposes other than for inserting screws. The sheet metal worker often uses a screw driver to open a hole in the sheet of metal and then he uses his hand snips to cut the required opening.

(D) Screwdriver. (Courtesy Malco Products Inc.)

Various types of files are used to remove small bits of metal as in removing burrs. A burr is a rough edge that remains on the metal after it has been cut, punched or drilled with a tool that is not sharpened properly.

File for removing small bits of metal. (Courtesy Nicholson File Co.)

SHEET METAL TYPES

The craftmanship and appearance of the finished job may be a fine piece of workmanship, but virtually useless if the wrong material is used. It is therefore extremely important to know what is the correct material for the given job.

Sheet metal material may be grouped into two common groups, namely, ferrous and non-ferrous, with each group including several types of metal for different uses. The first for discussion will be the ferrous types, commonly called steel.

Steel is the most commonly used material in the sheet metal shop. This is because it is inexpensive and available in alloys and with special coatings for a great variety of uses. The most commonly used types of sheet steel are galvanized, stainless and tin plate.

Sheet steel may be either coated or uncoated. The most commonly used coated sheets are galvanized and tin plate. Stainless steel is the most widely used non-coated solid sheet. Plain steel sheets are seldom used because of their susceptability to rust and corrosion.

Galvanized Sheet Metal is soft steel sheets coated with zinc. There are two methods of applying the zinc. In the most common one, the steel is dipped in an acid bath for cleaning and then is dipped in molten zinc. In the other, the coating is done by an electro-plating process. Electroplated sheets are distinguished by their even gray color and are used mainly for their ability to hold a painted surface.

Of all the sheet metals, galvanized is one of the least expensive. Its cost is in the same general range as plain steel sheets and steel bar. It is probably the most commonly used of all types of sheets in the general sheet metal shopwork. All types of roof flashing and gutters are made principally from galvanized sheet metal. Good quality galvanized sheet metal can be bent and straightened out several times without the zinc peeling from the sheet. Galvanized sheets bend well, with no problems in breaking when they are bent severly. It solders well, but welding is complicated by the fact that the zinc gives off toxic fumes and a residue which makes the weld itself more difficult. In addition, welding destroys the coating on the sheet, and for this reason galvanized sheet metal is seldom used in applications requiring welded joints.

Galvanized sheets can be obtained in widths of 24, 30, 36, 48 inches wide, with 36 being the most commonly stocked sizes. Sheet lengths generally are 96" or 120". However, other lengths and widths can be specially ordered.

Stainless Steel is also a widely used material in the sheet metal trade. As the name indicates, stainless steel has a high resistance to foreign or corrosive elements. It is also very easily cleaned and for these reasons, it is widely used in residential, institutional and restaurant kitchens for hoods, sinks, spatter guards, etc.

Stainless steel is a high grade steel to which has been added such elements as manganese, silicon, phosphorous, chromium, nickel and molybdenum. Of these elements, chromium and nickel are in the largest quantity. According to the particular type of stainless, it will contain from 10 to 30 percent chromium and from 10 to 25 percent nickel.

Stainless steel is classified according to its heat testing properties of the steel and also according to its alloy content. The type number is of great importance because handbooks list by type number the characteristics of each, the recommended uses, and the degrees of resistnace to various types of chemicals.

The common type of stainless steel used in the sheet metal shop is type 302. This is the type that is used for architectural work, containers of all sorts and for sinks and counters in restaurant work.

Stainless steel has a silver chrome appearance and generally can be easily recognized by its "grained" appearance. The grain in stainless steel is caused by the minute polishing practices and scratches generally found on most finishes. These all run in the same direction just as the grain in wood. And just as in wood, it is easier to cut the metal with the grain than across it. Unpolished stainless has no grain and has a dull gray finish very similar in appearance to unpolished aluminum.

Stainless steel comes in a solid sheet, not coated. This, along with its beauty and corrosion resistance, is its great advantage. It can be welded and the welded joints ground off and polished until the weld is not visible, yet its corrosion resistance is not affected.

The cost of stainless steel is high, running about seven times the cost of galvanized steel. However, in applications where galvanized may only last five years, stainless steel will last indefinitely. Because of its almost complete resistance to corrosion, the high cost of stainless does not necessarily mean it is the most expensive metal to use, since its long life often makes it the cheapest material to use in the long run.

Tin Plate is sheet steel coated with pure tin. It was once widely used in roofing, dairy equipment, food canning and other large scale applications, but has been largely replaced by stainless steel, aluminum and other materials.

Copper is a solid sheet usually recognized by its typical reddish color. Until the mid 1800's, copper, along with tin plate was the principal metal of the sheet metal worker. In fact, Paul Revere, immediately after the American Revolution, pioneered one of the first copper rolling mills in America.

The great advantage of copper is its high corrosion resistance. Another desirable feature of copper is its beauty. For many types of architecture, especially to supplement brickwork, copper adds warmth and color that cannot be duplicated by any other type of metal. Copper sheet is comparatively high in cost, running about three times the cost of galvanized steel. Copper is also used almost extensively in the manufacture of absorber plates in the solar industry.

Copper sheets are available in either cold rolled or hot rolled sheets. Cold rolled sheets are sheets that have been through a final process of running through finishing rolls. This gives the metal a smooth finish and work-hardens it to a half-hard condition.

Cold rolled copper is still softer than galvanized steel and is bent and formed easily. Though cold rolled copper is much stiffer than the hot rolled, it is not as rigid as steel sheets and usually a thicker sheet of copper is used than would be used for steel under the same conditions. Cold rolled copper is the type commonly used in the sheet metal shop.

In the sheet metal trade, copper sheets are specified by ounces per square foot. For example, 18 ounce copper means copper sheet that weighs 18 ounces per square foot. In other trades, copper sheet is sometimes designated by decimals of an inch thickness or by the American Wire or Brown and Sharpe Gage.

Aluminum. The main properties of aluminum are its light weight, corrosion resistance and appearance. Sheet aluminum weighs approximately 1/3 as much as sheet steels and is just about as strong. For these reasons, aluminum is sometimes used instead of galvanized steel for such items as exposed ductwork, gutters and downspouts, etc., where appearance, corrosion resistance and ease of handling are more important factors than economy.

Pure aluminum is too soft to hold a permanent shape in sheet form so the sheets are always manufactured as alloys. Alloying means that one or more metals are added to the pure alluminum to increase its strength and hardness. Some of the more common alloying metals are manganese, copper, chromium, silicon and magnesium. Very small quantities of these metals are required to give the desired physical properties for the aluminum. In fact, most alloys for sheet metal work are almost 99 percent pure aluminum.

Oxides of Metal. As mentioned previously, one of the determining characteristics of the selection of the appropriate sheet metal for the job, was the oxides of the metal. When considering the characteristics of the different sheet metals, one should also consider the importance of the oxides of that metal. Though we speak of the characteristics of the metal, what we are actually referring to most of the time, are the characteristics of the oxide of the metal.

Whenever a metal is exposed to air, the oxygen in the air combines with metal to form a chemical film over the metal. This chemical is called the oxide of the metal. A familiar example of an oxide is the rust that forms on uncoated iron and steel. This is called iron oxide. The green chemical that often forms on copper is an oxide of copper.

The importance of the oxide is that the characteristics of the oxide determine many of the characteristics of the metal. Rust (iron oxide) forms quickly and is porous and flaky. Since iron oxide is porous, it also allows moisture to seep through it and form more oxide underneath. Since it is flaky, as soon as a large amount of oxide is formed, it flakes off to expose more metal which will form more oxide. This action eventually eats through the metal which is the reason why plain steel is a poor metal to be exposed to corrosive conditions.

Stainless steel, on the other hand, forms an oxide that is transparent, tough and impervious to air and almost every chemical. This transparency is the reason stainless steel keeps its lasting beauty. The toughness of the oxide is the reason for the long life of stainless, since actually nothing ever contacts the metal itself.

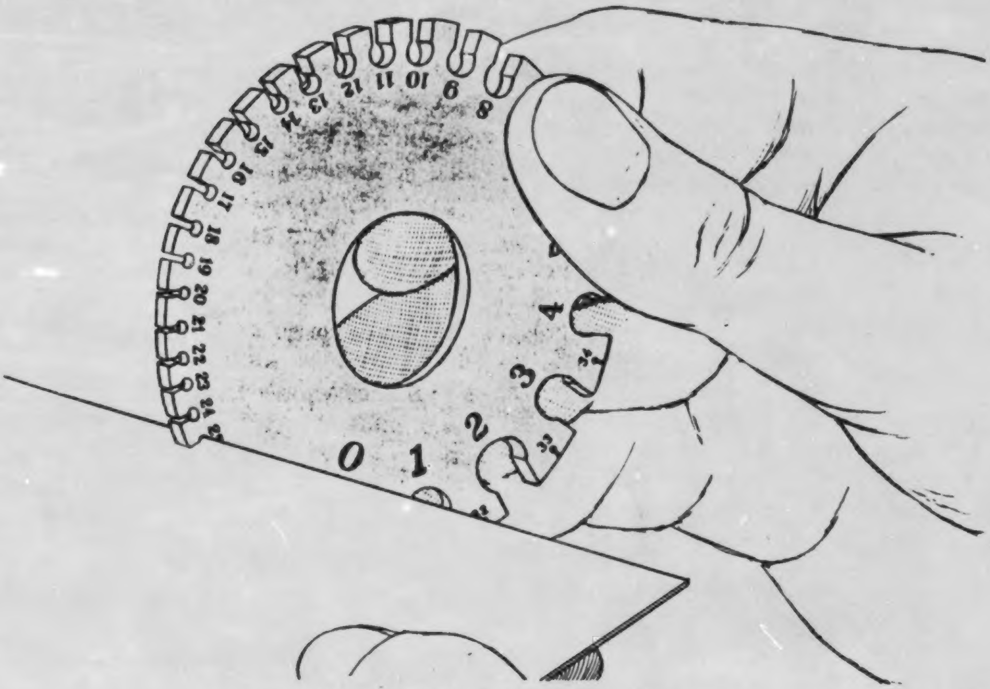
Copper and lead also have oxides which are impervious to air and most chemicals and this is why they are also long lasting.

Aluminum oxide is hard to dissolve and reforms immediately if removed. For this reason, aluminum is difficult to solder. In soldering, the oxide must be removed so that the solder contacts the metal directly. Where appearance is a point of major consideration in aluminum sheet metal, a process called anodizing is usually performed on the finished aluminum product to prevent corrosion of the aluminum in its raw state.

Sheet Metal Gage. The thickness of the piece of sheet metal is extremely important. It is referred to as the gage of the material. Each gage represents a specified metal thickness. The U. S. Standard Gage indicates the thickness of each gage number.

The lower gage numbers are the thicker sheets and the higher gage numbers are the thinner sheets. For example, a 26 gage sheet of metal is thinner than an 18 gage sheet of metal. The thickness of some sheet metal materials is not indicated by gage number. Copper sheets are measured in ounces per square foot. The thickness of aluminum sheets is usually referred to by decimal thickness.

A measuring tool can be used to find the gage of a sheet of metal when the gage is not marked on the sheet. This tool is called a "metal gage".



Sheet metal and wire gage.

The gage number is found adjacent to each slot. On the back side of the gage, the slot number gives either the decimal thickness or the fractional thickness. This gage is easy to use, merely find the smallest slot that the edge of the metal will fit into, the number adjacent to that slot indicates the gage of the piece of metal.

When measuring coated metals, extra care is required. These metals are described in the previous information given in this unit. Due to the coating, the metal measures thicker than it really is. In measuring this metal, you should determine only the thickness of the metal under the coating. The actual gage of the metal is one gage thinner than indicated by the gage. For example, if the gage indicates that a sheet of coated metal is 22 gage, it is actually 23 gage metal.

The following tables give the gage number, approximate pounds per square foot, the thickness equivalent or the sheet gage number and its thickness range for various types of sheet metal.

Galvanized Carbon Steel Sheets

Galv. Sheet Ga. No.	Approx. Lb Per Sq Ft	Thick. Equiv., Galv. Sht. Ga. No.	Thick. Range (inches)
8	7.03125	0.1681	.1756-.1607
9	6.40625	0.1532	.1606-.1458
10	5.78125	0.1832	.1457-1308
11	5.15625	0.1233	.1307-.1159
12	4.53125	0.1084	.1158-.1009
13	3.90625	0.0934	.1008-.0860
14	3.28125	0.0785	.0859-.0748
15	2.96875	0.0710	.0747-.0673
16	2.65625	0.0635	.0672-.0606
17	2.40625	0.0575	.0605-.0546
18	2.15625	0.0516	.0545-.0486
19	1.90625	0.0456	.0485-.0426
20	1.65625	0.0396	.0425-.0382
21	1.53125	0.0366	.0381-0352
22	1.40625	0.0336	.0351-.0322
23	1.28125	0.0306	.0321-.0292
24	1.15625	0.0276	.0291-.0262
25	1.03125	0.0247	.0261-.0232
26	0.90625	0.0217	.0231-.0210
27	0.84375	0.0202	.0209-.0195
28	0.78125	0.0187	.0194-.0180
29	0.71875	0.0172	.0179-.0165
30	0.65625	0.0157	.0164-.0150
31	0.59375	0.0142	.0149-.0138
32	0.56250	0.0134	.0137-.0131

Stainless Steel Sheets
(Approximate Weights and Thicknesses)

Thickness Ordering Range (inches)	Gauge No.	Approximate Decimal Parts of an Inch	Av. Wt. per sq ft (in lb) for Chrome Nickel—Cold-Rolled Alloys
.161 to .176	8	.17187	7.2187
.146 to .160	9	.15625	6.5625
.131 to .145	10	.140625	5.9062
.115 to .130	11	.125	5.5200
.009 to .114	12	.109375	4.5937
.084 to .098	13	.09375	3.9374
.073 to .083	14	.078125	3.2812
.066 to .072	15*	.0703125	2.9521
.059 to .065	16	.0625	2.6250
.053 to .058	17	.05625	2.3625
.047 to .052	18	.050	2.1000
.041 to .046	19	.04375	1.8375
.036 to .040	20	.0375	1.5750
.033 to .035	21	.034375	1.4437
.030 to .032	22	.03125	1.3125
.027 to .029	23	.028125	1.1813
.024 to .026	24	.025	1.0500
.0199 to .023	25	.021875	0.9187
.0178 to .0198	26	.01875	0.7875
.0161 to .0177	27	.0171875	0.7218
.0146 td .0160	28	.015625	0.6562
.0131 to .0145	29	.0140625	0.5906
.0115 to .0130	30	.0125	0.5250
.0105 to .0114	31	.0109375	0.4594
.0095 to .0104	32	.01015625	0.4265

Sheet Gauges and Weights
(Steel and Nonferrous Metals)

Carbon Steel			Brass		
USS Ga. No.	Revised Mfrs. Thickness for Steel	Approx. Wt. per sq ft (lb)	B & S Ga. No.	Dec. Thickness	Approx. Wt. per sq ft (lb)
1	.28125	11.250	1	.2893	12.75
2	.26562	10.620	2	.2576	11.35
3	.2391	10.000	3	.2294	10.11
4	.2242	9.375	4	.2043	9.002
5	.2092	8.750	5	.1819	8.015
6	.1943	8.125	6	.1620	7.138
7	.1793	7.500	7	.1443	6.358
8	.1644	6.875	8	.1285	5.662
9	.1494	6.250	9	.1144	5.041
10	.1345	5.625	10	.1019	4.490
11	.1196	5.000	11	.1907	3.997
12	.1046	4.375	12	.0808	3.560
13	.0897	3.750	13	.0720	3.173
14	.0747	3.125	14	.0641	2.825
15	.0673	2.812	15	.0571	2.516
16	.0598	2.500	16	.0508	2.238
17	.0538	2.250	17	.0453	1.996
18	.0478	2.000	18	.0403	1.776
19	.0418	1.750	19	.0359	1.582
20	.0359	1.500	20	.0320	1.410
21	.0329	1.375	21	.0285	1.256
22	.0299	1.250	22	.0254	1.119
23	.0269	1.125	23	.0226	.9958
24	.0239	1.000	24	.0201	.8857
25	.0209	.875	25	.0179	.7887
26	.0179	.750	26	.0159	.7006
27	.0164	.687	27	.0142	.6257
28	.0149	.625	28	.0126	.5552
29	.0135	.562	29	.0113	.4979
30	.0120	.500	30	.0100	.4406

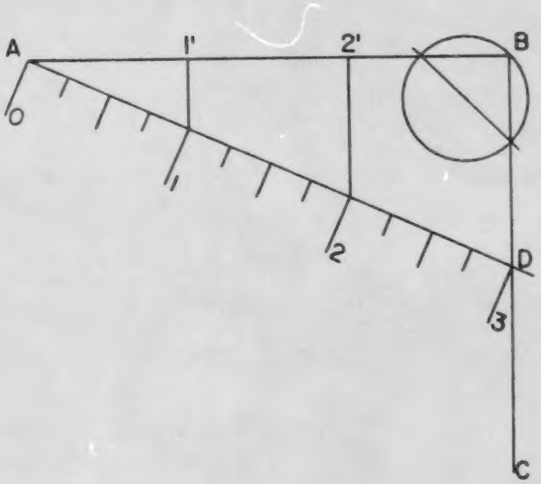
Sheet Gauges and Weights
(Steel and Nonferrous Metals)

Copper			Zinc		
Stubs Ga. No.	Dec. Thickness	Approx. Wt. per sq ft (lb)	Zinc Ga. No.	Dec. Thickness	Approx. Wt. per sq ft (lb)
1	.300	13.94	24	.125	4.70
2	.284	13.20	23	.100	3.75
3	.259	12.04	22	.090	3.37
4	.238	11.07	21	.080	3.00
5	.220	10.22	20	.070	2.62
6	.203	9.420	19	.060	2.25
7	.180	8.360	18	.055	2.06
8	.165	7.660	17	.050	1.87
9	.148	6.875	16	.045	1.68
10	.134	6.225	15	.040	1.50
11	.120	5.575	14	.036	1.35
12	.109	5.065	13	.032	1.20
13	.095	4.410	12	.028	1.05
14	.083	3.860	11	.024	.90
15	.072	3.338	10	.020	.75
16	.065	3.020	9	.018	.67
17	.058	2.695	8	.016	.60
18	.049	2.280	7	.014	.52
19	.042	1.952	6	.012	.45
20	.035	1.627	5	.010	.37
21	.032	1.484	4	.008	.30
22	.028	1.302	3	.006	.22
23	.025	1.162	....	....	....
24	.022	1.022	....	....	....
25	.020	.928	....	....	....

Geometric Principles. In sheet metal work, the development of the pattern is of utmost importance. Frequently the pattern may be used as a template for guidance in making many pieces of the same size. The scribe would be used to scribe around the template for production of many other pieces as near an exact duplicate of the template as possible. In other uses, the template is used strictly as a pattern or guidlines for the manufacturing or building of a particular sheet metal product.

The knowledge of geometry and geometric principles is of extreme importance in development of the pattern layout. Knowledge of parallel lines, straight lines, curved lines, radii, arcs tangeant to two lines, arcs tangeant to a line in a circle, arcs tangeant to two circles intersecting lines, angles and the terminology associated with angles, 180° angles, obtuse angles, acute angles, right angles, right triangles are all essential to the successful layout of the pattern used in sheet metal work. The final product of the pattern is a combination of circles, curves, triangles, straight lines, rectangles, squares, etc. So it is absolutely essential that the student attempting to make the pattern have a very thorough knowledge of the geometric principles or principles of geometry as they apply to the sheet metal trade.

Frequently it is necessary to use geometry in dividing two or more lines, to divide lines into equal parts with a rule or square, to establish a point of bisection of a line using a set of dividers or trammel points. Division of lines into two or more equal parts is also done by the process of use of the divider and/or trammel points. Angle bisection into two or more equal angles or angles of unequal value also done through the use of dividers and/or trammel points. Divisions of circles into equal parts with their associated equal angles is also done by the same tools. It is without a doubt one of the most important parts in learning how to establish a pattern for the part to be produced that the student have a very thorough knowledge of the principles of geometry.



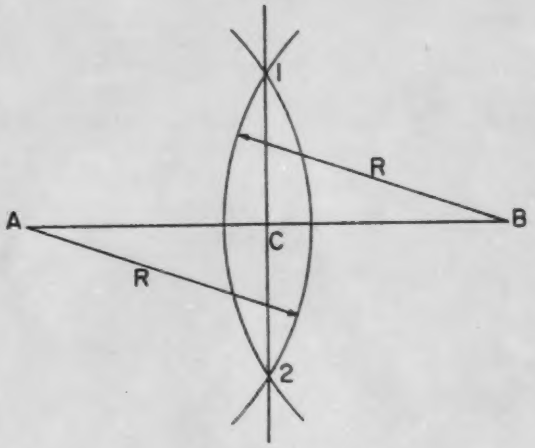


Fig. 4-4a Line bisection.

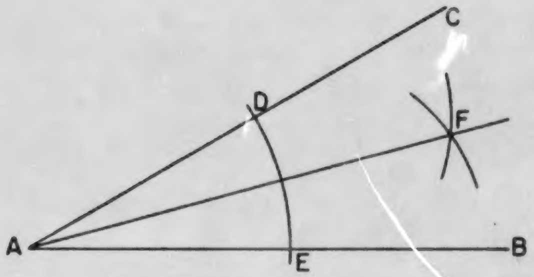


Fig. 4-5a Angle bisection.

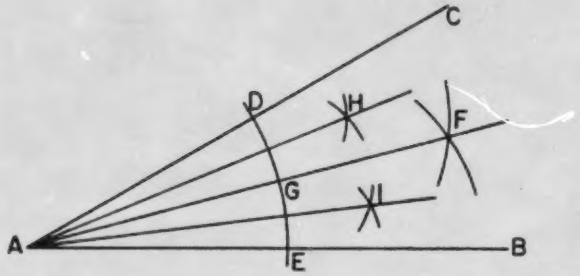


Fig. 4-5b Angle bisection to form four equal angles.

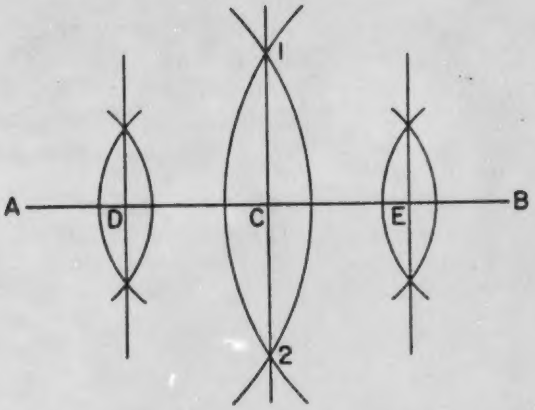


Fig. 4-4b Division of a line into four equal parts. This process may be continued to divide the line into any even number of equal parts.

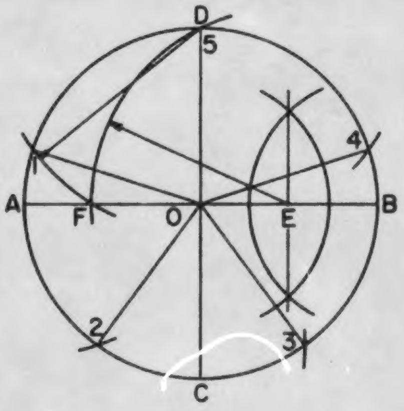

D
5
4
A
F
O
E
B
2
3
C

Fig. 4-6 Division of circle into 5 equal parts and angles.

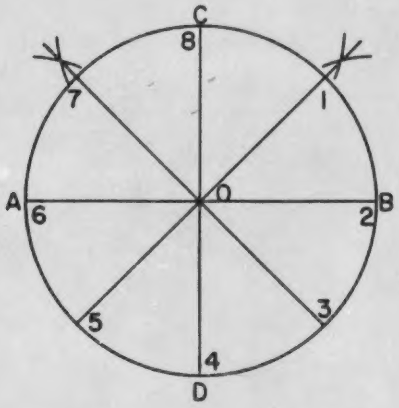

C
8
7
1
O
A
6
2
B
5
3
4
D

Fig. 4-7 Division of a circle into 8 equal parts and angles.

Views and Projections. Sheet metal patterns and job layouts are developed from one or more views of the object. It is possible to have front, side, top, bottom and auxiliary or profile views, depending on the position of the eye in viewing the object.

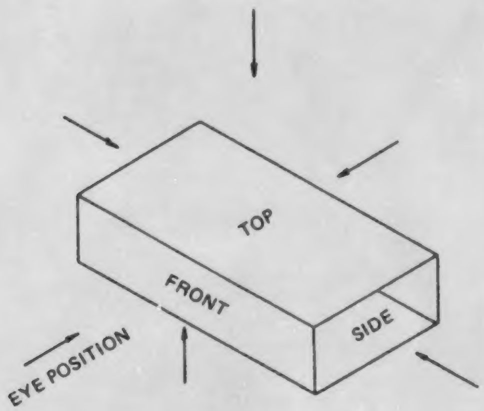

TOP
FRONT
SIDE
EYE POSITION

Fig. 6-1 Position of eye in viewing sheet metal duct.

The projection of each view is the profile of the object on a flat plane as shown in the figure below.

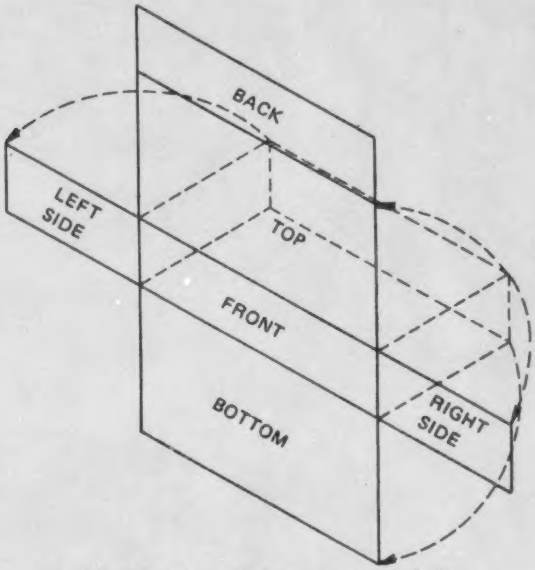

BACK
LEFT SIDE
TOP
FRONT
BOTTOM
RIGHT SIDE

Fig. 6-2 Revolving each view onto a vertical plane.

The projection of a top or bottom view to a horizontal plane is termed a plan view.

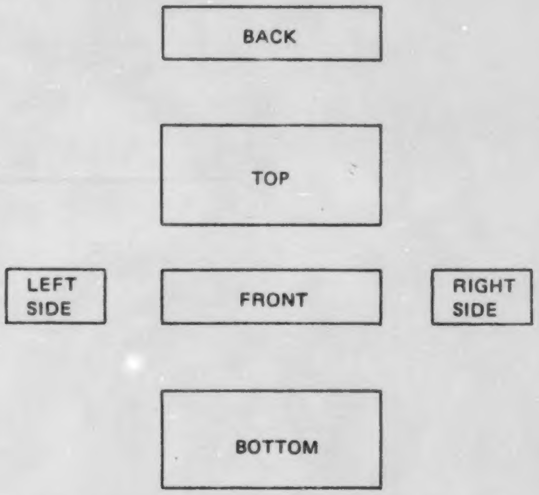

BACK
TOP
LEFT SIDE
FRONT
RIGHT SIDE
BOTTOM

Fig. 6-3 Top and bottom are plan views; side and back are elevation views. Side view is also a profile view.

The projection of a front or side view to a vertical plane is termed an elevation view. Plan views and elevation views are arranged to that the relationship of every point of the object exists in each view. Thus, the plan view is placed directly above and in line with the front elevation view. The side elevation view is placed to the right or left of the front elevation view and aligned with it.

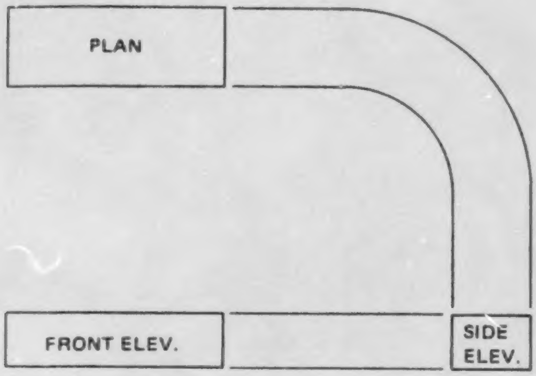

PLAN
FRONT ELEV.
SIDE ELEV.

Fig. 6-4 Alignment of views.

All visible points are shown with solid lines and those hidden below the visible surface, but known to exist, are shown with dotted lines.

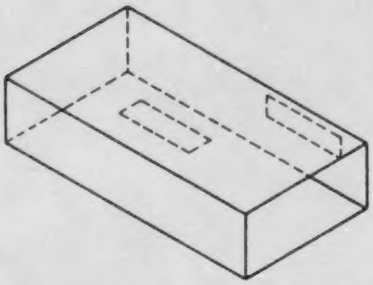


Fig. 6-5a Sheet metal duct with take-off holes cut in the bottom and back.

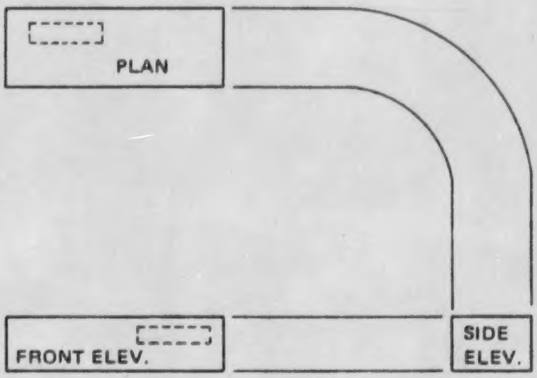


Fig. 6-5b Views showing holes in hidden surfaces.

Lets illustrate the above principles by working with the following drawing.

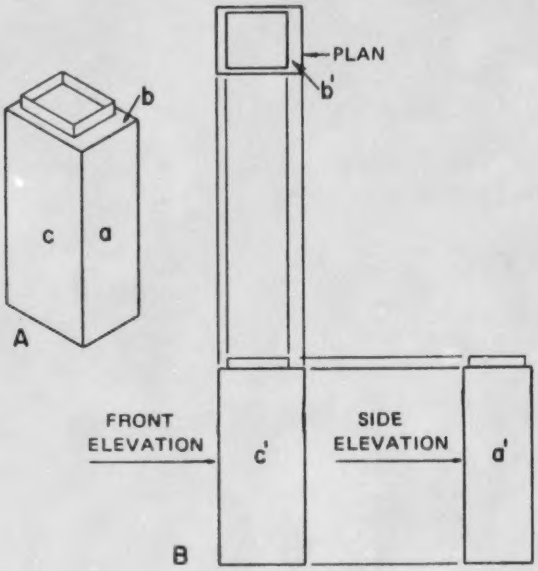


Fig. 6-6 Furnace casing.

The objective is to construct a plan and elevation view from the object shown above.

1. Select the front view as (C) and draw the front elevation to size (C prime).
2. Project vertical lines from C prime and draw the plan view B prime aligned with C prime.
3. Project horizontal lines from C prime and draw the side elevation view A prime aligned with C prime.

In sheet metal work, it may be necessary to complete a partial drawing to obtain a true layout. This frequently happens and is necessary in order for the pattern to be developed properly.

As another practice exercise, lets construct the side elevation from plan view and a front elevation view from the figure shown below.

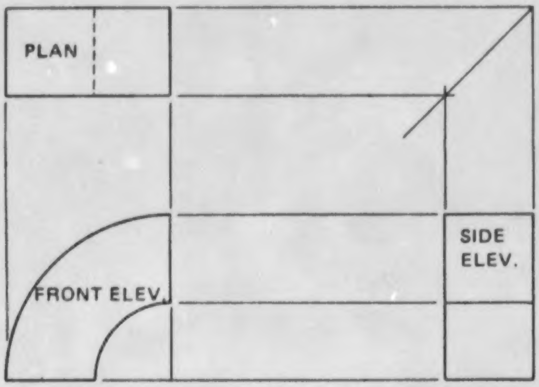


Fig. 6-7 90° square elbow.

1. From the given plan and elevation views, project all horizontal points to the right for a right side elevation view.
2. Select a suitable distance from the front elevation and scribe a vertical line.
3. At the point of intersection of the vertical line and the inside or lowest horizontal line projected from the plan view, scribe a 45 degree line.
4. Extend vertical lines downward from the intersection points of the 45 degree line and the horizontal lines from the plan view to intersect horizontal lines projected from the front elevation.
5. The side elevation is formed by the intersection of the projected horizontal and vertical lines.

In some cases where the plan and elevation views are not sufficient to make a pattern layout, an auxiliary view is necessary. An auxiliary view is the projection of a surface on any plane other than the horizontal or vertical planes. Problems dealing with the intersection of cones, cylinders and other geometric solids make use of auxiliary views.

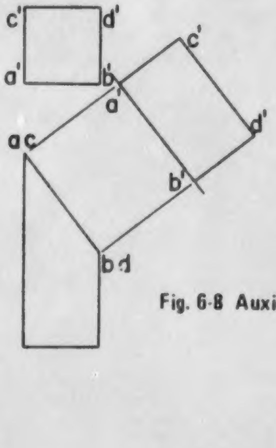


Fig. 6-8 Auxiliary view square duct.

To construct an auxiliary view from a plan view, an elevation view such as the one shown above, use the following plan:

1. Project all points on inclined surface ab-bd along lines drawn perpendicular to the surface.
2. At a suitable distance from the inclined surface, scribe a line parallel to it and intersecting the perpendicular projection lines.
3. On the perpendicular projection lines, lay off distances a'c' and b'd' from the intersection of the perpendicular and parallel lines.

Complete the auxiliary view by connecting c' to d'. The auxiliary view shows the exact size and shape of the inclined surface which is not shown in either the plan or elevation views.

In the previous exercises, we have been working with square or rectangular plan and elevation views. Let us now work with an auxiliary view of an oblique cylinder such as the one shown below.

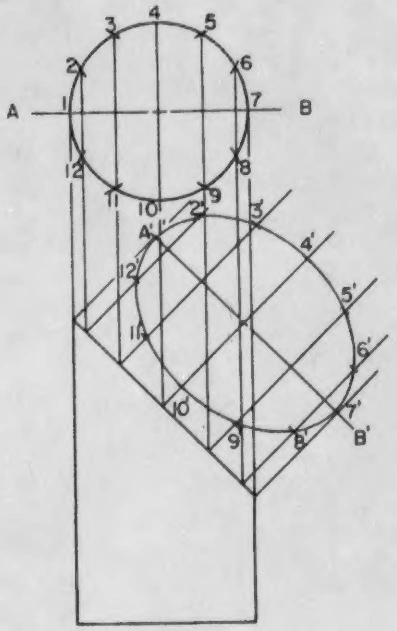


Fig. 6-9 Auxiliary view oblique cylinder.

To construct the auxiliary view of an oblique cylinder from the plan and elevation views use the following steps.

1. Divide the plan view into 12 equal parts.
2. Project the points located in step 1 to the inclined surface in the elevation view.
3. Project the points on the inclined surface along lines drawn perpendicular to the inclined surface.
4. At a suitable distance from the inclined surface, scribe a centerline A'B' parallel to the surface and intersecting the perpendicular projection lines.

5. Using the distance from the centerline AB to each division point in the plan view, transfer the distances about centerline A'B' on the corresponding projection lines to establish points 1,2,3,4,5,6,7,8,9,10,11,12.
6. Connect the prime points, using a French curve or by drawing a freehand curve, to complete the auxiliary view.

All of the above methods may be used in the development of a pattern for making of a sheet metal layout pattern. Many times the projected views may merely be put together in order to form the complete pattern. However, some times further projection and additional geometric lines are required in order to produce a pattern that may be used for the production of the desired sheet metal product.

Notches. To make a layout for a complete job, the sheet metal worker must be able to visualize where the metal is to be cut to ease the fitting of the pieces together and to prevent the overlapping of surplus material which causes bulges at the seams and edges. The types of notches used are the square, straight, slant, V, half V, Pittsburg and wire. Some patterns will require a combination of several types of notches.

Notching is the last step in pattern layout. Seams, laps and stiffening edges are all marked on the pattern before the notches are made. The sheet metal worker must determine the type of notch to be used on the job. Too large a notch will leave a hole in the finished job, while too small a notch will result in buckling and overlapping.

The square notch shown below, is either square or rectangular in shape. It is used to eliminate the surplus material on the corner of boxes and pans.

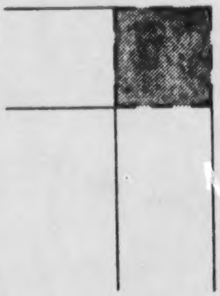


Fig. 9-1 Square notch.

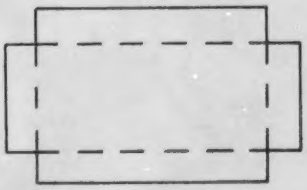


Fig. 9-2 Square-notched pattern.

The straight notch shown below is a straight cut in the edge of the pattern. It is used when a dovetail is made or for a flange at an outside corner.

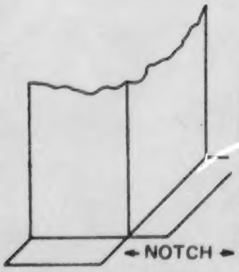


Fig. 9-3 Straight notch.

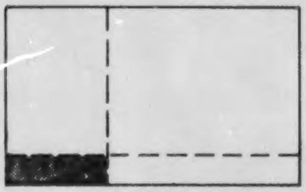


Fig. 9-4 Straight-notched pattern.

A slant notch is a cut at a 45 degree angle to the corner of the pattern to prevent the overlapping of the edges when single hems are to meet at right angles.

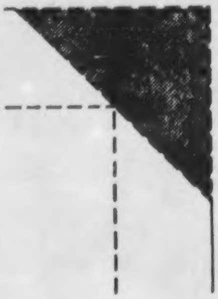


Fig. 9-5 Slant notch.

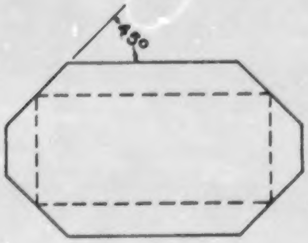


Fig. 9-6 Slant-notched pattern.

The full V notch shown below, has both of its sides cut at 45 degree angles to the edge of the pattern. The sides of the notch meet at a 90 degree angle. The full V notch is used when the ends of the boxes are to be double seamed or when the job has a 90 degree bend and an inside flange.

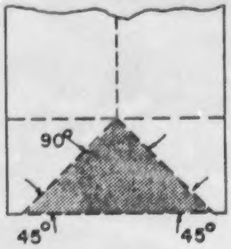


Fig. 9-7 Full V-notch.

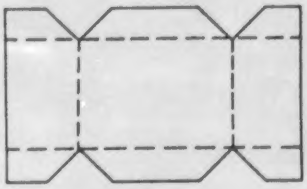


Fig. 9-8 Notched pattern.

The half V notch, as shown below, is a notch that meets at a 15 to 30 degree angle and is laid out at right angles to the edge of the pattern. The half V notch is used on the bent edges of square fittings and on double seams.

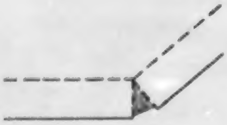


Fig. 9-9 Half V notch.

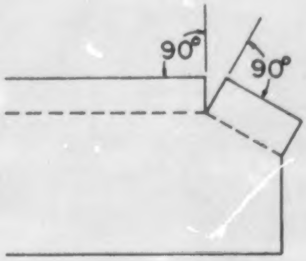


Fig. 9-10 Notched pattern.

The Pittsburgh notch is used in the fabrication of fittings containing a slanted side, such as a change transition. The Pittsburgh notch is shown below.

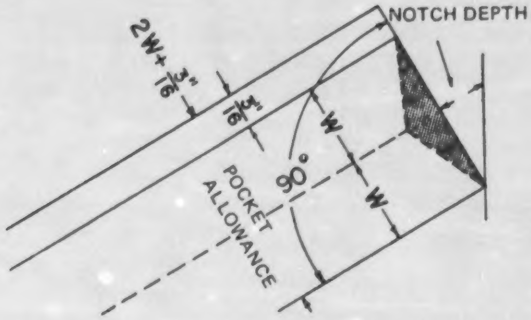


Fig. 9-11 Pittsburgh notch.

The fitting changes in size and angle according to the amount of slant and the size of the Pittsburgh lock. The purpose of the notch is to prevent overlapping and provide clearance for a drive connection.

The wire notch, as shown below, is a combination of a square notch and a half V notch. The angle of the lower part of the notch is usually 5 to 10 degrees to the edge of the pattern. This notch is used to avoid overlapping of the material where the wired edge crosses a seam.

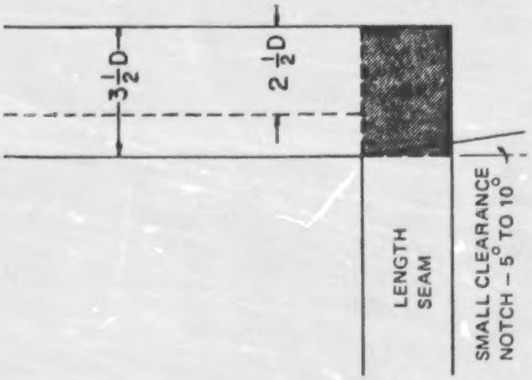


Fig. 9-13 Wire notch.

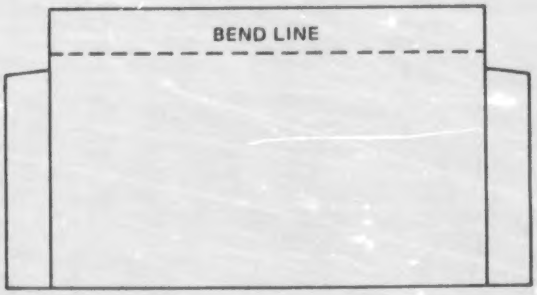


Fig. 9-14 Notched pattern.

When full patterns for an object are to be made, a combination of several notches may be required. The sheet metal worker should study the object to be formed, determine the seams to be used and the edges required and decide on the type and placement of the notches necessary for easy forming. Seam allowances should be calculated along with the notch depth in some cases. If the pattern is in more than one piece, each piece should be visualized, including its size and how it connects to the other pieces of the pattern.

Due to the complexity and the many different kinds of seams required by the professional sheet metal worker, we will not cover these seams in this unit of instruction. We will however, cover the use of various edges, such as hems and wire edges. If the instructor and/or the student desires to know more about seams used in sheet metal layout, it is recommended that reference 3, unit 7, pages 36 through 43 be studied very carefully. This particular book, Zinngrabe and Schumacher, Practical Layout for the Sheet Metal Shop, gives a very good treatment of the different kinds of seams used in sheet metal work.

Edges. When sheet metal is cut to size for a job, the edges are called raw edges. Raw edges are sharp, lack strength and have a crude appearance. Therefore, this type of edge must be eliminated when a job is formed. The methods used to remove a raw edge are hemming, inserting wire, or attaching band or angle iron. These methods add strength, improve the appearance of the job and provide additional safety. The type of edge to be used depends on the kind of metal used, the thickness of the metal and the strength required of the finished job.

A single hem, as shown below, is formed by folding the edge of the metal 180 degrees.

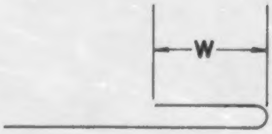


Fig. 8-1 Single hem.

The hem can be folded manually or by machine. The size of the hem varies with the thickness of the metal and the degree of edge stiffness required. For thicker metal, the hem must be larger. For practical purposes, a single hem less than 3/16 inch wide should not be used. The allowance for a single hem is equal to the width of the hem. The allowance for the hem shown below is equal to the width of W.

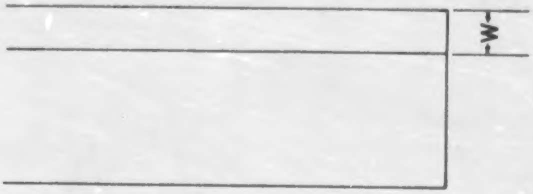


Fig. 8-2 Layout for single hem.

This allowance W is measured with a marking gage, rule and straight edge or by gage setting on the machine.

The double hem, as shown below, is formed by folding the edge of the metal twice.

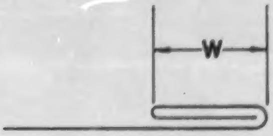


Fig. 8-3 Double hem.

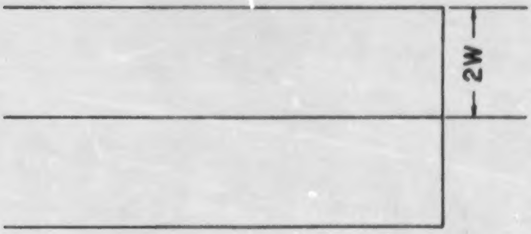


Fig. 8-4 Layout for double hem.

Two successive 180 degree bends are made. The brake or bar folder can be used or the edge can be formed by hand.

The double hem is used where additional strength and edge stiffness are required. The width of the hem depends on the size of the job and the material used.

The allowance for a double hem is equal to twice the width of the finished hem. The hem allowance is laid out using the same tools that were used for the single hem. When the metal to be formed is thicker than 24 gage, an allowance must be made for the thickness of the metal. Subtract one metal thickness from the finished width (W) for the first bend; subtract one metal thickness plus 1/32 inch for the second bend. For example: For a 1/4 inch double hem, the width required for the double hem would be A = 2 x 1/4 which is equal to 1/2 inch of metal.

The wire edge, shown below, is formed by folding or wrapping the edge of the metal around a wire or rod.

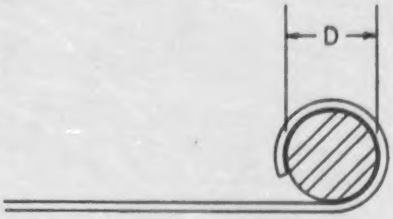


Fig. 8-5 Wire edge.

The metal edge can be prepared manually for the wire or it can be formed on a bar folder, brake or turning machine.

The purpose of the wire edge is to eliminate the raw edge and add strength and rigidity to the metal. Wire edges are always placed on the outside of a job, unless otherwise specified. The allowance for a wire edge is equal to two and a half times the wire diameter for 22 gage and lighter metal.

For metal with a thickness greater than 22 gage, the wire edge allowance is two and a half times the wire diameter plus five times the metal thickness. The wire edge allowance is laid out on the edge of the sheet before forming. In most cases, the wire allowance is added to the finished dimension of the pattern.

The band iron method of edging is very simple in that the sheet metal is folded over the edge of the band iron or over the top of the angle iron. Depending upon the thickness and width of the banding iron and the angle iron as to the amount of material required.

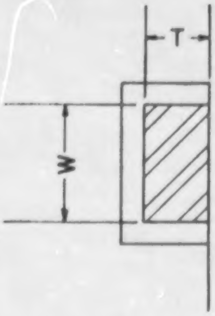


Fig. 8-7 Band iron edge.

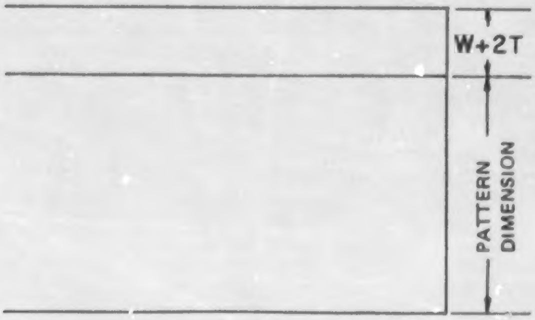


Fig. 8-8 Layout for band iron edge.

The angle iron edge is used where great strength and stiffness are required along an edge. The allowance for an angle iron edge varies with the type of job. Some jobs require a complete edge wrap while other jobs require only a partial wrap. The allowance for a complete wrap is equal to one and one half times the width of the angle leg, as shown below.

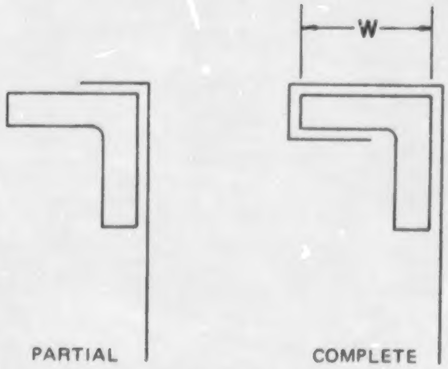


Fig. 8-9 Angle iron edges.

When forming a box with hems or with inside or outside flanges, these must be formed before the overall shape of the box is formed. For example, the first box that we shall look at is one that is formed without hems. The box shown below is marked in accordance with the proper forming procedure. Refer to this sequence when you study the following steps:

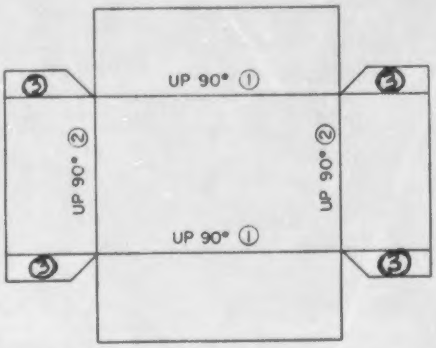
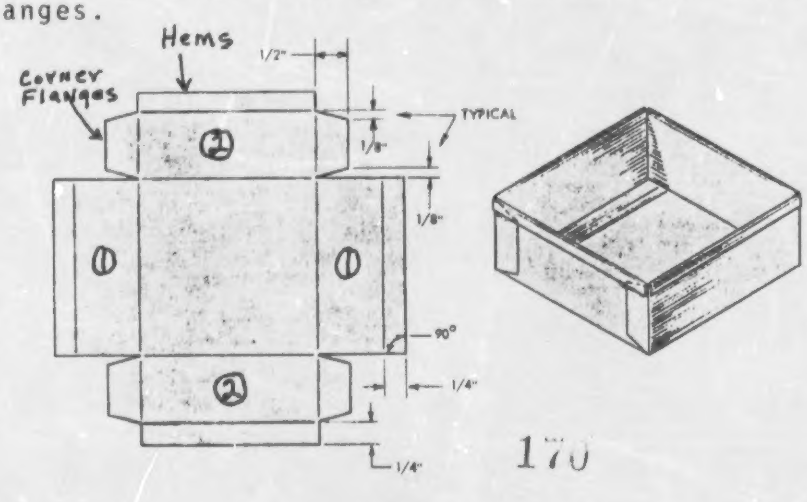


Fig. 11-10. Forming sequence for a box.

1. When a box or a pan has corner laps, these corner laps should always be formed over the entire pattern first. The corner laps in the sketch above are marked as number 3.
2. Corner laps can be formed to the inside or outside of the box by slightly kinking the starting edge of the formed lap inside or outside.
3. Always form the hems and outside or inside flanges before forming the overall shape of the box.
4. Form the line marked up 90^0 number 1. Since two lines are marked identically, either line can be formed first.
5. Form the other line marked up 90^0 number 1.
6. Select and attach the correct size finger or fingers to the top leaf on the next fold line.
7. Form one line marked up 90^0 number 2. This one will have two of the flanges marked number 3.
8. Form the other line marked up 90^0 number 2. This side also has the corner flanges marked number 3.

Let us now look at the formation of a box containing both hems and corner flanges.



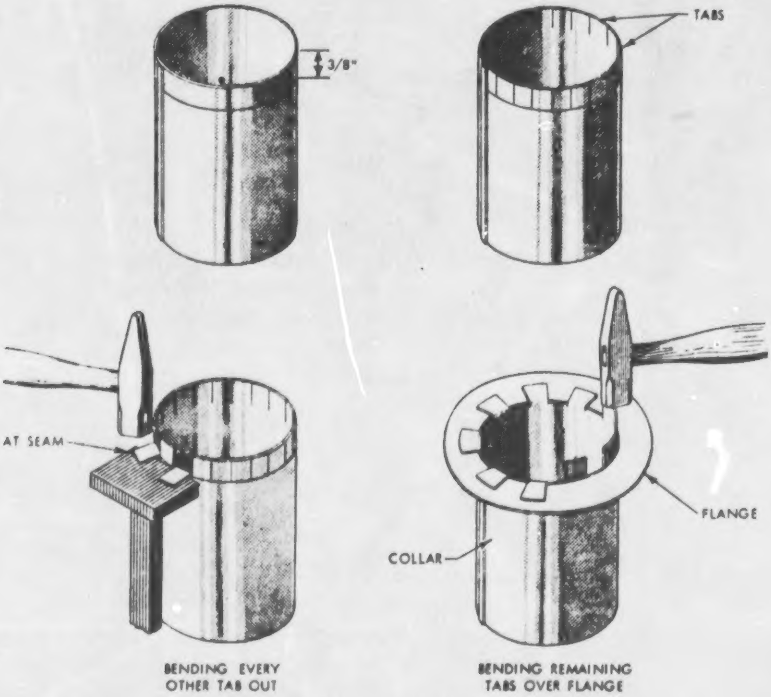
The procedure for forming the box shown above are as follows:

1. Form all hems, 4 sides, 180° downward.
2. Form all corner flanges (4 each) to conform to either the inside or outside of the sides marked number 1.
3. Form the sides marked number 1 up 90°.
4. Select the appropriate finger for the pan brake and form the sides marked number 2 up 90° while carefully guiding the corner flanges inside the hems if the flanges are to be placed on the outside of the sides marked number 1. If the corner flanges are to go inside the side marked number 1, then there is no need to guide them inside the hems, since this direction will be irrevelent.

NOTE TO THE INSTRUCTOR

Careful guidance may be required during the procedures of forming this particular box. If it is the student's first attempt at working with sheet metal or sheet metal substitute, the student may find this task somewhat difficult but with your assistance, will soon discover that it is only a matter of planning each step properly after the layout to come up with the finished product that is both useful and neat in appearance.

A fitting frequently used in Solar air systems is called a dove tail seam.



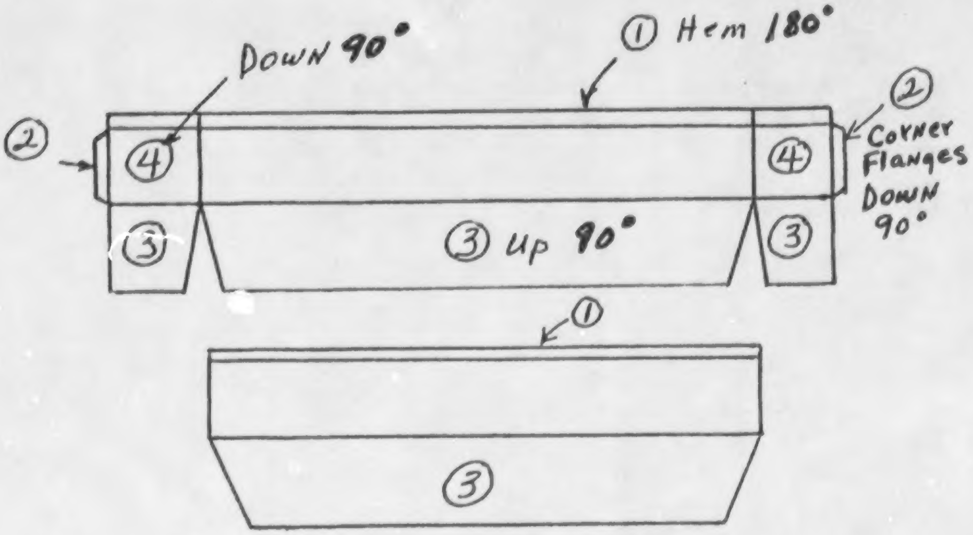
BENDING EVERY OTHER TAB OUT

BENDING REMAINING TABS OVER FLANGE

Fig. 11-13. Making a dovetail seam.

This type of connection is often made to the underside of air collectors for provisions of attaching round flexible ducts to the parallel bank of air collectors.

The pitch pan is used in sealing roof penetrations. The length, width and height of the pitch pan shall be determined by the instructor depending upon the amount of kinds of materials available. Therefore, the only directions given are the pattern layout sketches and the folding procedures. This pitch pan is of two piece construction with the corner flanges being attached to the opposite side with the use of solder or rivets.



1. Select the appropriate material for the manufacture of this pitch pan and lay it out according to the dimensions provided by the instructor in the pattern as shown above.
2. Fold the hem upward and then all the way down to 180° bend. The hem is marked by the number 1.
3. Fold the corner flanges number 2, down 90°.
4. Fold the roof flashing flanges marked number 3 up 90°.
5. Fold the end pieces marked number 4 down 90°.

This should complete the forming of this pitch pan and the attachment of the opposite side can be accomplished through the use of rivets, solder or glue if cardboard was chosen as the material for construction.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

ROOFING, FLASHING AND PITCH PANS

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

ROOFING, FLASHING AND PITCH PANS

Introduction

Roof construction requires a skilled craftsman and knowledge of stresses far beyond the scope of this course;however, many solar systems can be mounted on existing roofs if the Solar Technician has an awareness of roof structures and their load capacities. If there is any doubt, a professional should be consulted.

Roof Mounting - Roof-mounted collectors for water heating are mounted with standoff racks or brackets. Preparation of the roof area and the procedure for anchoring to the roof members are the same in either case. In new-home installations, much of the mounting work can be performed after the roof has been framed and sheathed, but before felting. This reduces solar installation labor but increases the roofer's work; however, the finished roof's structural integrity is better if most of the penetrations are made before it is finished.

The best position for a collector is over the common roof joists, figure 4-10. Both the roof ridge and areas where roof slope changes should be avoided because they increase the collector's vulnerability to wind loading and heat loss.

The collector or its supports should be anchored directly to the roof joists, not to the sheathing. The procedure is as follows:
1. Choose optimum site for collector.
2. Locate the specific rafters for mounting.
3. Measure and mark the roof penetration points for anchoring.
4. Prepare roof surface.
5. Anchor brackets to rafter.
6. Seal the roof.

The rafters or roof joists may be located by different methods. If the attic or crawl space is large enough to permit free access and working room, the anchoring points can be located from the inside. Drill pilot holes beside the rafter at the desired anchoring points; this locates these points for the workers on the roof, and roof preparation can begin. If adequate access to the attic is not possible, rafters can be located by looking for nails in the fascia board, which will give the location and spacing of the trusses. Approximate location of the mounting points can be determined by measuring across the roof ridge and popping a chalk line between the ridge and fascia along the run of the truss, figure 4-11. Keep in mind that the run of the truss is not perfectly straight, so the chalk line will be close to but not precisely on the truss run. Many installers use the variation in tone associated with a hammer blow to locate the run of the truss.

After the anchoring points have been selected (which will depend on the particular collector(s) and mounting hardware), prepare the roof for penetration.

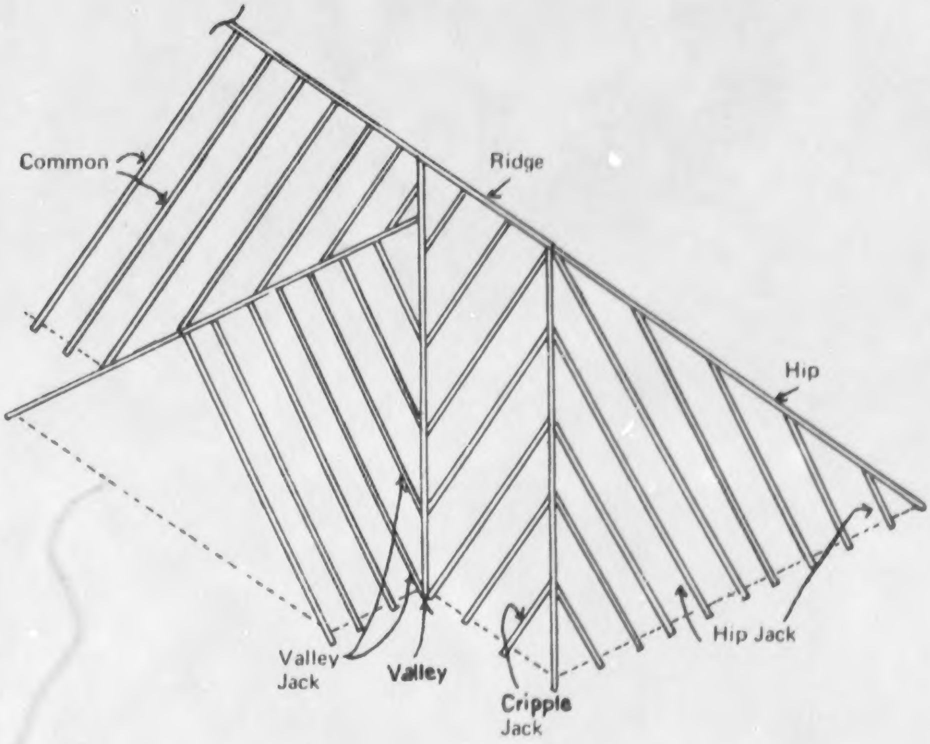

Common
Ridge
Hip
Hip Jack
Valley Jack
Valley
Cripple Jack

FIGURE 4-10
Roof Structures

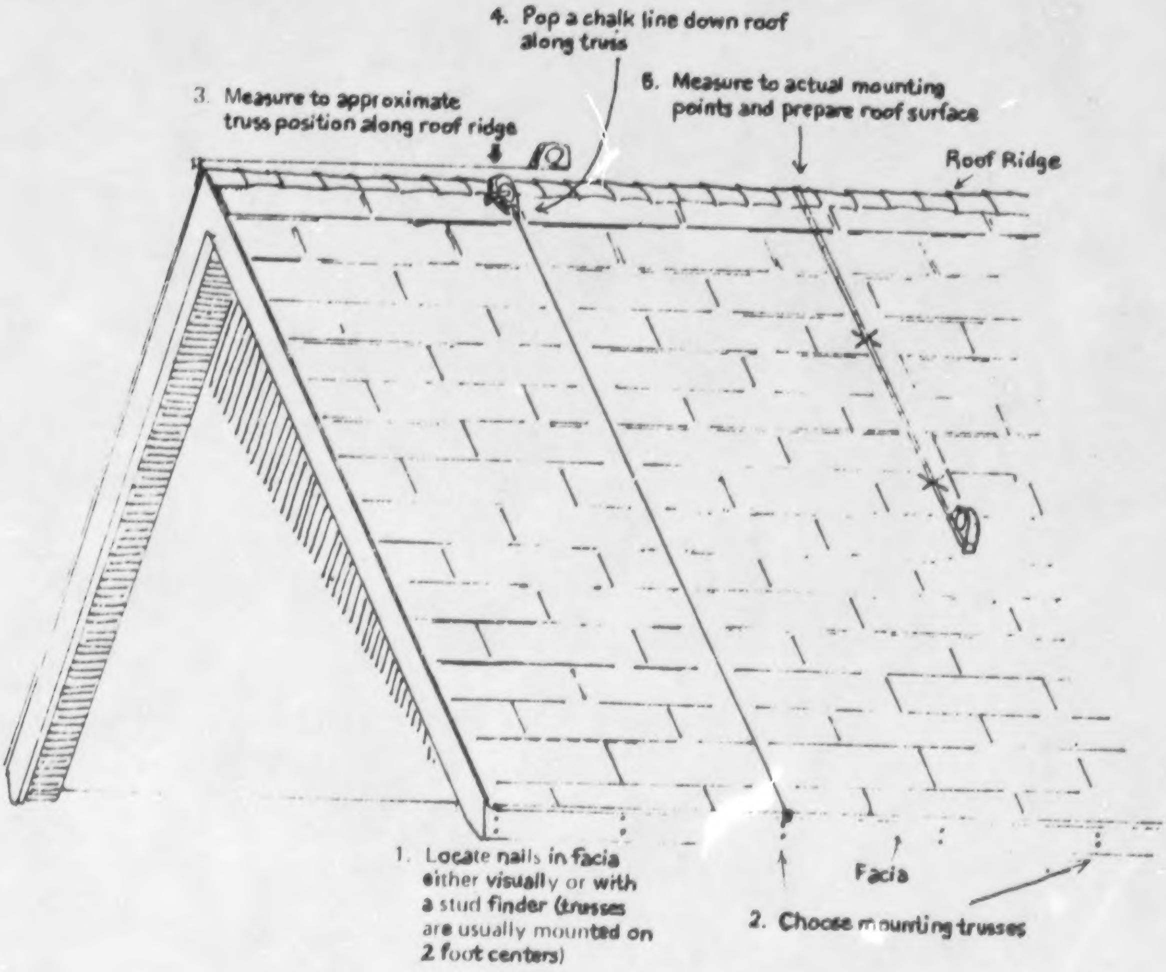

4. Pop a chalk line down roof along truss
3. Measure to approximate truss position along roof ridge
5. Measure to actual mounting points and prepare roof surface
Roof Ridge
1. Locate nails in facia either visually or with a stud finder (trusses are usually mounted on 2 foot centers)
Facia
2. Choose mounting trusses

FIGURE 4-11
A Method of Locating Mounting Points

Roof Preparation. Asphalt shingles are stapled in an overlapping pattern over the felted plywood that comprises the sheathing. Brackets can be mounted directly over the shingles; no special preparation is necessary. Holes for the mounting bolts may be drilled through the shingles. Old, brittle asphalt shingles may break when walked on.

Tile roofs, on the other hand, require extensive preparation. When walking on these roofs, care must be taken not to break the tiles or slip on loose tiles. On barrel tiles walk on the low spots only. Broken tiles must be replaced, increasing installation tion cost and time. Tiles in the area of the anchoring spot may be broken with a hammer and removed. Remove as few tiles as possible, because the area must be sealed watertight later and must be attractive. When the tiles are removed, the exposed waterproof membrane can be softened with paint thinner; if it is in good condition, remove as little as possible. Punch small pilot holes with a nail to find the exact truss location.

A builtup roof is composed of roof tar covered with a liberal amount of loosely-bound gravel which reinforces the semi-viscous roof tar and protects it from excessive heat and ultraviolet rays. The rafters, in this case, can be located by hammering on the roof surface--the roof pebbles will not jump when a rafter is struck. Remove as much of the gravel as possible; then use paint thinner to soften the roof tar down to the felt. Again, find the rafter position by making small pilot holes.

Bracket Mounting and Sealing. If working room is available in the attic or crawl space, the use of spanners is the preferred anchoring method. The spanner is a two-by-six clamped to two or more rafters by means of a threaded rod. Using a spanner on two rafters with one roof penetration is not recommended, because it allows the sheathing to flex and form a low spot on the roof, which could cause ponding of water. The best mounting of a spanner is across three or four rafters, with the threaded rods close to the two outer rafters. This method relies on the strength of many rafters rather than one.

The threaded rod should be secured with nuts and washers below the spanner in the following order:

1. Large pattern, zinc-plated fender washer.
2. Helical spring lock washer.
3. Coat threads with VC-3 or equivalent.
4. Hex nut (zinc-plated).

Remember that the threaded rod is always zinc-or cadmium-plated, so get plated hex nuts for proper fit. The purpose of VC-3 or equivalent thread coating is to resist loosening of the nut caused by vibration due to wind buffeting, figure 4-12.

If the attic or crawl space is too small for safe access, J-bolts or lag screws must be used. Use only 3/8 inch or 1/2 inch diameter

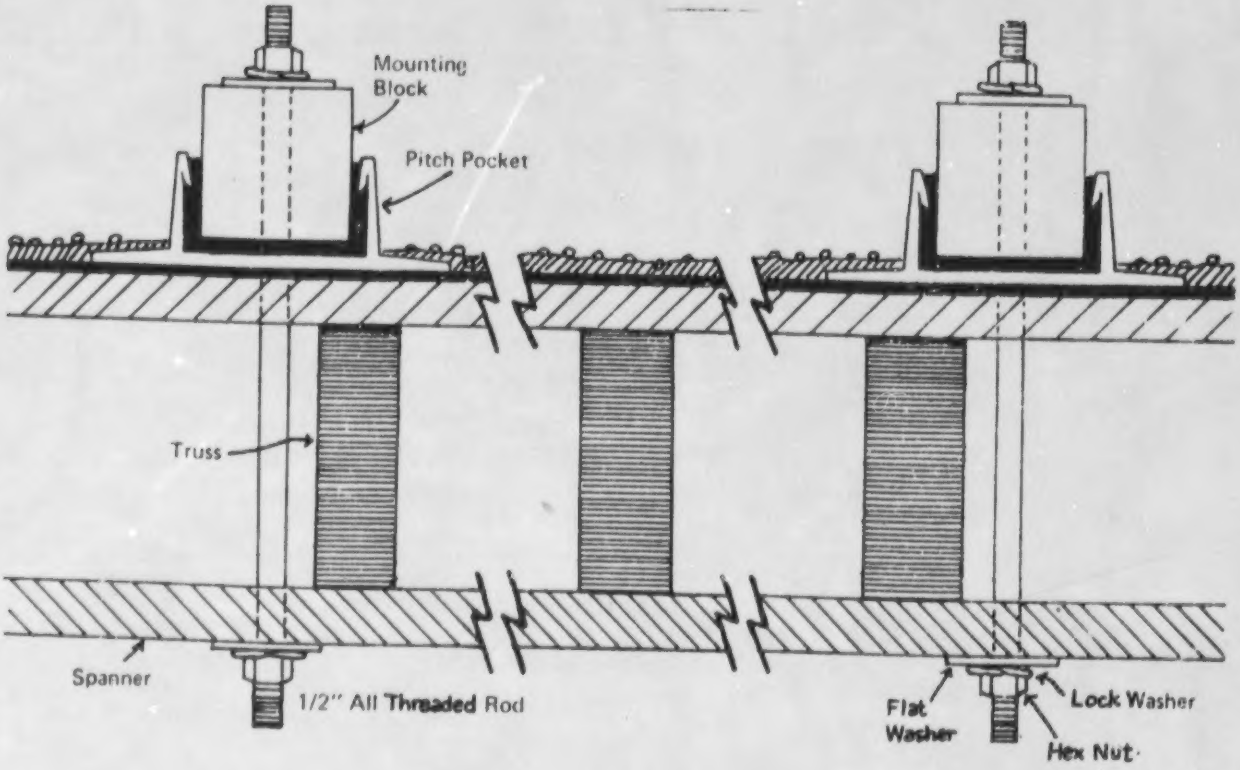

Mounting Block
Pitch Pocket
Truss
Spanner
1/2" All Threaded Rod
Flat Washer
Lock Washer
Hex Nut

FIGURE 4-12
Spanner Mounting

lag screws at least 4 inches long. When using J-bolts, they must be long enough to grip under a rafter and still have full threading outside the roof sheathing.

When lag screws are used for mounting, pitch pockets may be required on most types of roofs. Pitch pockets can be made from 603 sheet copper or sheet stainless steel.

First drill pilot hole into centerline of truss to length of bolt penetration. Apply silicone sealant liberally around pilot hole opening. Place pitch pocket and pre-drilled mounting block on roof. Next apply neoprene pad, flat washer, lock washer and bolt with silicone between pad and flat washer. Apply silicone around pitch pocket border and bolt hole, and fill pocket with viscous hot pitch. Figure 4-13 illustrates proper procedure.

For J-bolt mounting, drill hole directly beside rafter; hole size must be slightly larger than bolt diameter. Fit bold through mounting block and pitch pocket, then insert bole (J side first) through the hole in the roof, and work the J underneath the rafter. Pull up on rafter before tightening nut; use double nuts and lock-washer to tie down bolt. Use the sealing technique described in the previous paragraph (figure 4-14).

Collector Attachment. If the collector is to be rack-mounted, the racks should be mounted next. Make sure that the rack (if adjustable) is tilted to the desired angle and the collector (when mounted) can be gravity-drained. The installer should follow the collector manufacturer's guidelines regarding particulars of rack adjustment and attachment. Make sure the rack is structurally sound and firmly secured. If collector and rack are made of dissimilar metals, they must be electrically isolated to prevent corrosion.

If the collector is to be mounted with standoffs, allow at least 1 inch clearance between collector bottom and roof surface to prevent water or material buildup. The bracket to collector attachment must also be strong enough to withstand potential wind loads. Again, follow manufacturer's instructions.

After the collector has been mounted, check the entire assembly for rigidity.

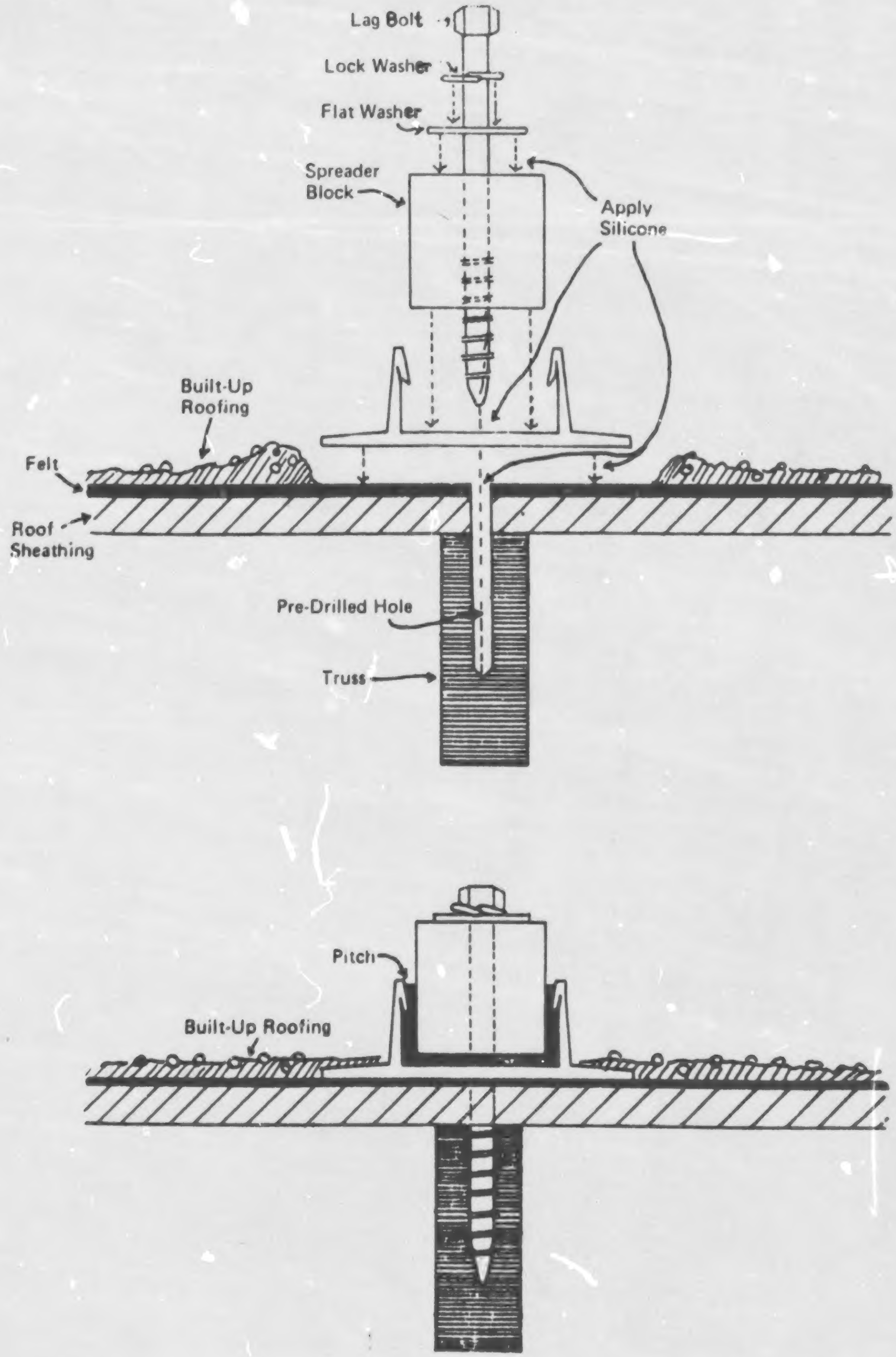

Lag Bolt
Lock Washer
Flat Washer
Spreader Block
Apply Silicone
Built-Up Roofing
Felt
Roof Sheathing
Pre-Drilled Hole
Truss
Pitch
Built-Up Roofing

FIGURE 4-13
Assembly of Lag Bolted Mounting

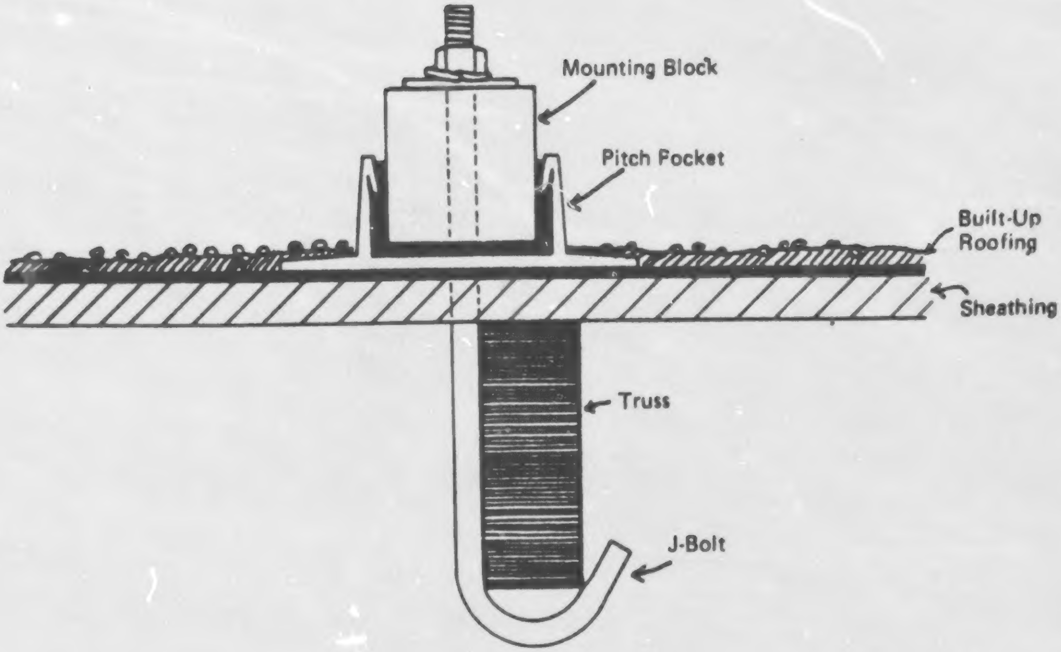

Mounting Block
Pitch Pocket
Built-Up Roofing
Sheathing
Truss
J-Bolt

FIGURE 4-14
J-Bolt Mounting

Roof Piping and Penetrations

Select the spots to penetrate the roof for the piping runs as they approach the mounted collector. In some cases it may be desirable to pipe both the feed and the return lines through the same penetration. In gravity drain systems, make sure that the chosen spot will allow for drainage, which means that the feed line should penetrate the roof downslope from the collector. All lines should be pitched at least 1/4 inch per foot of pipe run to allow drainage. Roof penetrations should be made between trusses to allow for slight flexing of the pipe from wind buffeting and thermal expansion.

There are several methods of penetration that employ good engineering practices. All roof penetrations should comply with accepted practices of the National Roofing Contractor's Association (NRCA). If there are any conflicts between this manual's recommendations and the local building codes, the installer must, of course, follow the building codes.

One method of providing a watertight penetration involves a standard plumbing roof vent stack flashing. If this method is used, the rubber boot must be protected from ultraviolet light (figure 4-15).

Another common method is to make a flat copper flashing which is penetrated by the fluid line (copper pipe). A galvanized washer is then soldered or brazed to the pipe and flashing at their junction (figure 4-15).

A less desirable method is to bring both pipes up through a pitch pocket. Although this is often done, an open-bottom pitch pocket requires some maintenance and inspections over the life of the solar system.

For larger commercial installations on flat, builtup roofs, the installer should follow specific recommendations of the NRCA manual for eliminating pitch pockets.

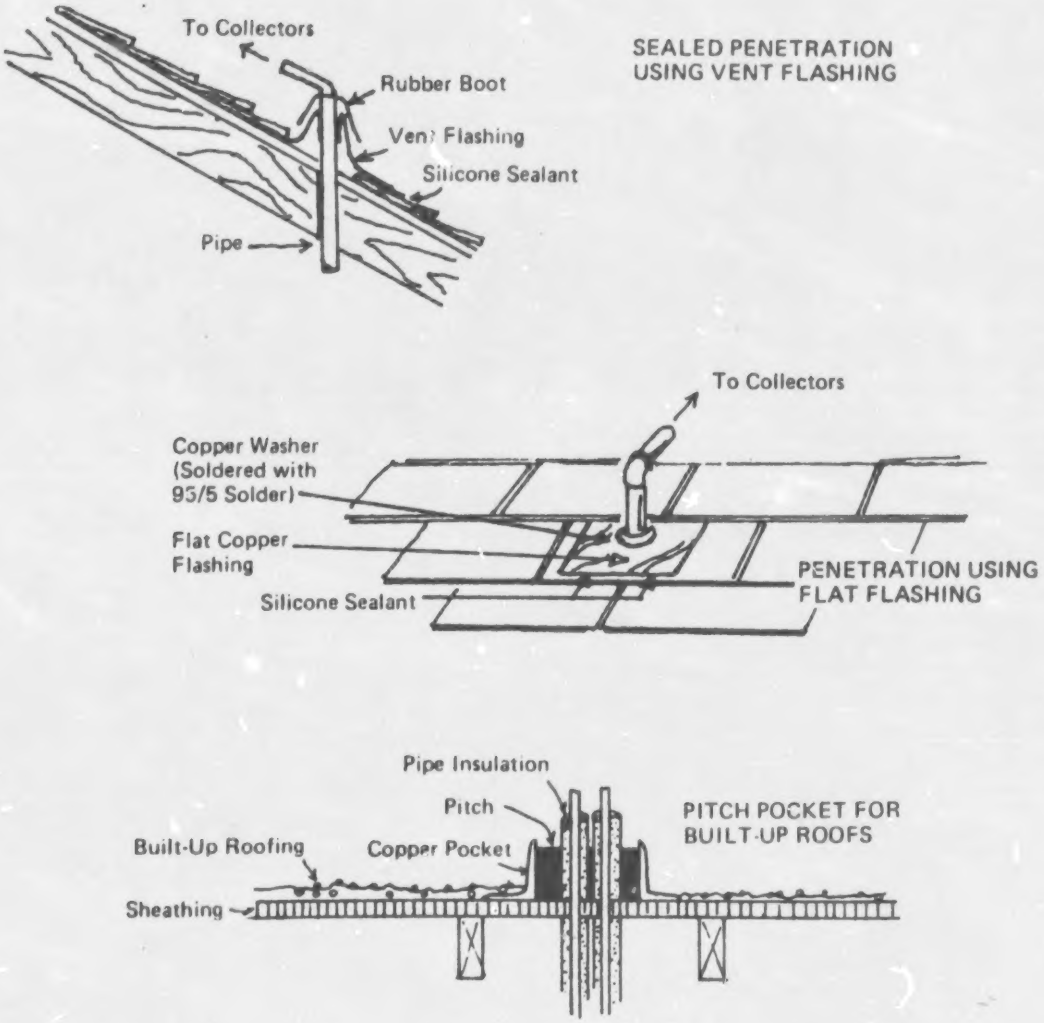

To Collectors
Rubber Boot
Vent Flashing
Silicone Sealant
Pipe
SEALED PENETRATION USING VENT FLASHING
To Collectors
Copper Washer (Soldered with 95/5 Solder)
Flat Copper Flashing
Silicone Sealant
PENETRATION USING FLAT FLASHING
Pipe Insulation
Pitch
Built-Up Roofing
Copper Pocket
Sheathing
PITCH POCKET FOR BUILT-UP ROOFS

FIGURE 4-15
Types of Sealed Roof Penetrations

Roof Types

An understanding of the various types of roofs and their construction will facilitate making choices as to where the collectors can be mounted.

Although there is a wide variation in roof shapes, most of them can be classified among the following types, figure 9-1.

Flat roof: In this type, the roof is supported on joists that also carry the ceiling material. It may have a slight slope to provide drainage.

Shed roof: The simplest type of pitched (sloped) roof. Sometimes called a lean-to-roof since it is often a part of a larger structure. Used in contemporary designs where the ceiling is attached directly to the roof framing.

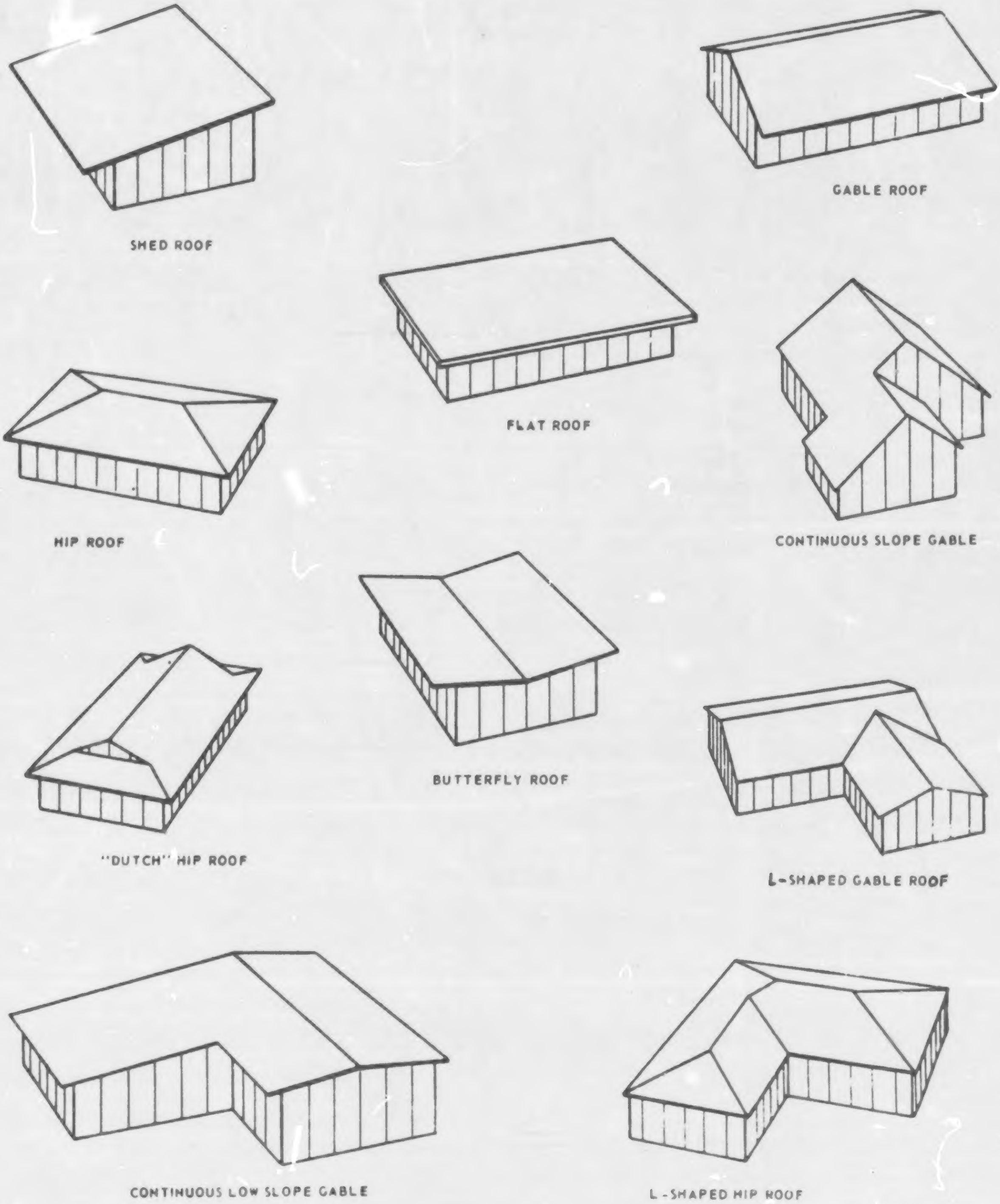
Butterfly roof: Sheds water toward the middle. Its use has become practical with the advent of improved methods in flashing, drainage, and waterproofing. Since this type tends to accumulate ice and snow, its use is usually limited to warmer climates.

Gable roof: Two surfaces slope from the center line of the structure forming gables on each end. Because of the simplicity of its design and relative low cost, the gable roof is used extensively for residential construction.

Hip roof: Consists of four sloping sides. The line where the adjacent sides intersect is called the hip. One advantage of this type results from the protective overhang formed on end walls as well as side walls.

Gambrel roof: A variation of the gable roof where each slope is broken, usually near the center. This style is used on two-story construction and permits more efficient use of the second floor level. Dormers, figure 9-2, above, are usually included. Typical of colonial America and the period immediately following.

Mansard roof: Similar to the hip roof except that each of the four sides has a double slope. The lower slope approaches the vertical while the upper slope is more or less flat. Like the gambrel roof, the main advantage is the additional space formed in the rooms on the upper level. The name is derived from its originator, architect Francois Mansart (1598-1666). Figure 9-2, below.



SHED ROOF

GABLE ROOF

FLAT ROOF

HIP ROOF

CONTINUOUS SLOPE GABLE

BUTTERFLY ROOF

"DUTCH" HIP ROOF

L-SHAPED GABLE ROOF

CONTINUOUS LOW SLOPE GABLE

L-SHAPED HIP ROOF

Fig. 9-1. Types of roofs used in residential construction.

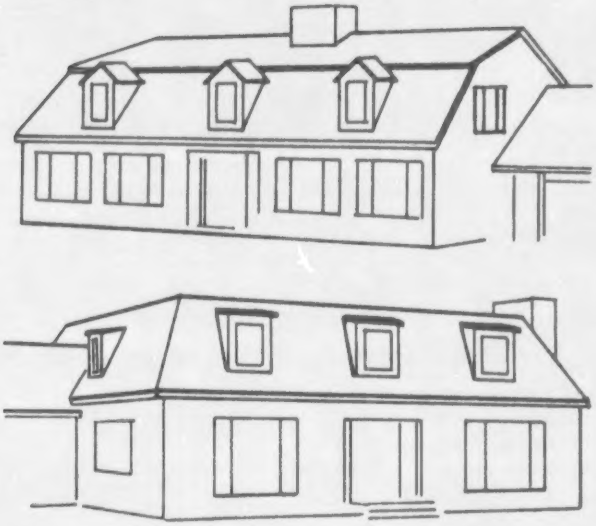


Fig. 9-2. Traditional roof designs. Above. Gambrel. Below. Mansard.

Parts of Roof Frame

The plan view of a roof, figure 9-3, is a composite of several roof types with the kinds of rafters identified.

The COMMON rafters are those that run at a right angle (plan view) from the wall plate to the ridge. A plain gable roof consists entirely of rafters of this kind. HIP rafters also run from the plate to the ridge, but at a 45 deg. angle. They form the intersections of the adjacent slopes of a hip roof. VALLEY rafters extend diagonally from the plate to the ridge in the hollow formed by the intersection of two roof sections.

Three kinds of jack rafters are: the HIP JACK which is the same as the lower part of a common rafter, but intersects a hip rafter instead of the ridge. The VALLEY JACK is the same as the upper end of a common rafter, but intersects a valley rafter instead of the plate. The CRIPPLE JACK rafter, also called a cripple rafter, intersects neither the plate or the ridge and is terminated at each end by hip and valley rafters. The cripple jack rafter may be further defined as a hip-valley cripple jack or a valley cripple jack.

Parts of a Rafter

Rafters are formed by laying out and making various cuts. Figure 9-4 shows the cuts for a common rafter and the sections formed. The ridge cut allows the upper end to fit tightly against the ridge. The bird's-mouth is formed by a seat cut and plumb (vertical) cut when the rafter extends beyond the plate. This extension is called the overhang or tail. When there is no overhang, the bottom of the rafter is terminated by a seat cut and a plumb cut that extends upward.

Layout Terms and Principles

Roof framing is a practical application of geometry; the area of mathematics that deals with the relationships of points, lines, and surfaces. It is based largely on the properties of the right triangle where the horizontal distance is the base; the vertical distance is the altitude; and the length of the rafter is the hypotenuse.

If any two sides of a right triangle, figure 9-5, are known, the third side can be found mathematically. The formula used is: $H^2=B^2+A^2$, where H is the hypotenuse, B is the base and A is the altitude. The solution involves extracting the square root which is a rather time consuming process. The answer could also be found through the application of trigonometric functions.

In on-the-job use, the carpenter uses the tables on the framing square or a direct layout method that is rapid and practical for his work.

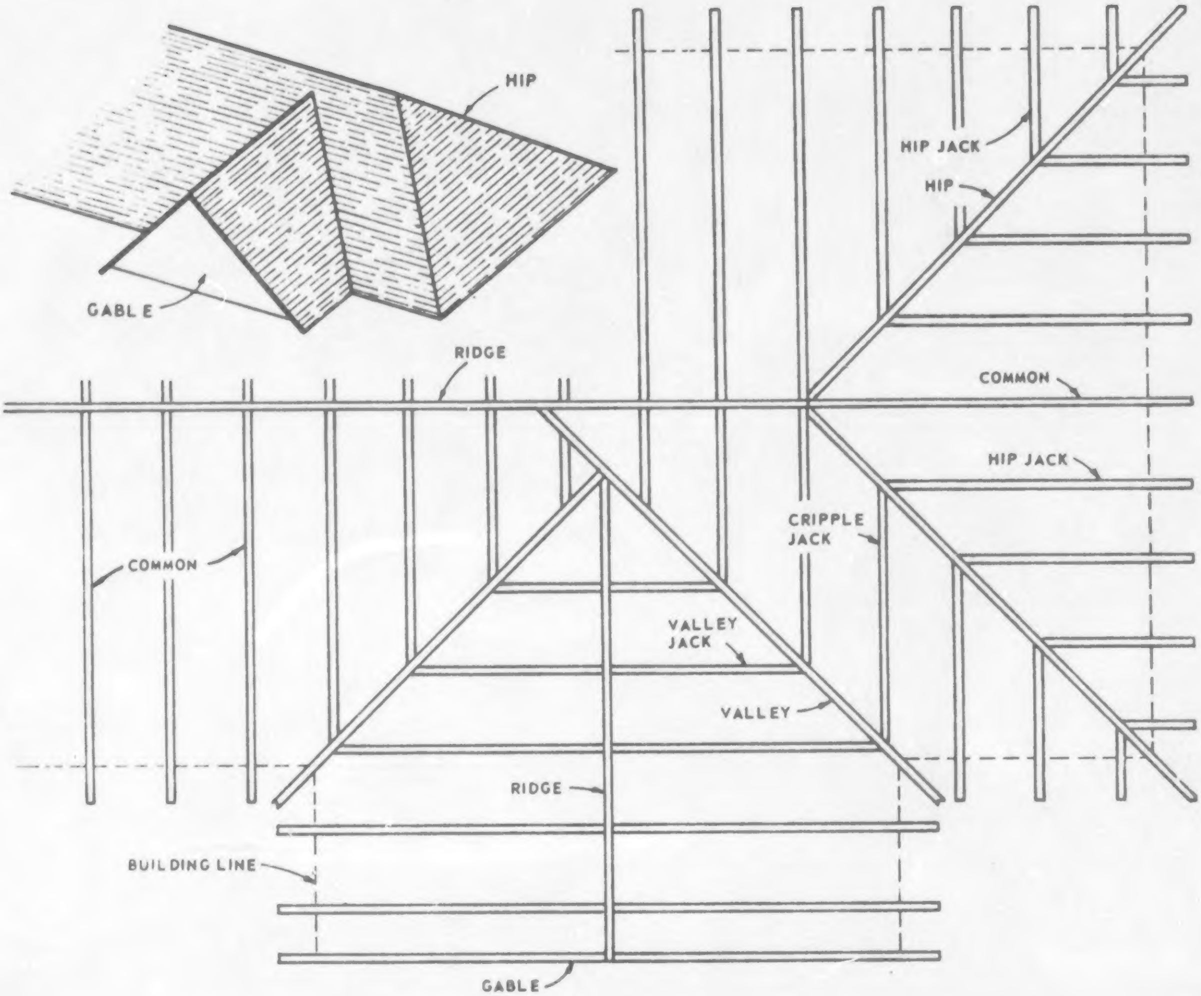

HIP
GABLE
RIDGE
HIP JACK
HIP
COMMON
HIP JACK
CRIPPLE JACK
COMMON
VALLEY JACK
VALLEY
RIDGE
BUILDING LINE
GABLE

Fig. 9-3. Plan (top) view of a roof frame, showing ridges and various kinds of rafters. Inset shows how roof will appear when finished.

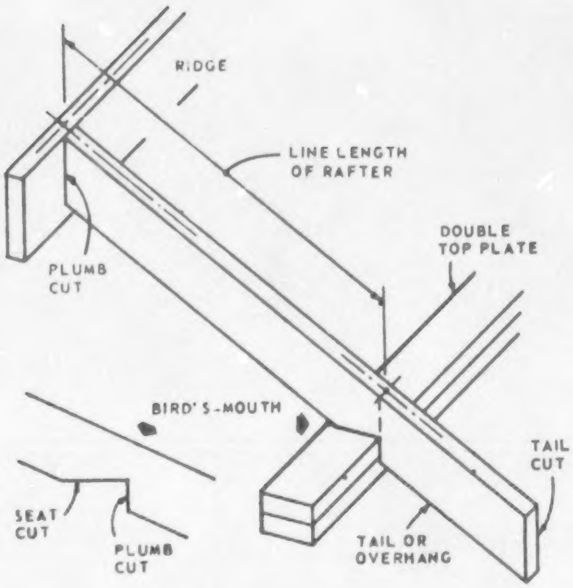

RIDGE
LINE LENGTH OF RAFTER
DOUBLE TOP PLATE
PLUMB CUT
BIRD'S-MOUTH
SEAT CUT
PLUMB CUT
TAIL OR OVERHANG
TAIL CUT

Fig. 9-4. Parts of a rafter.

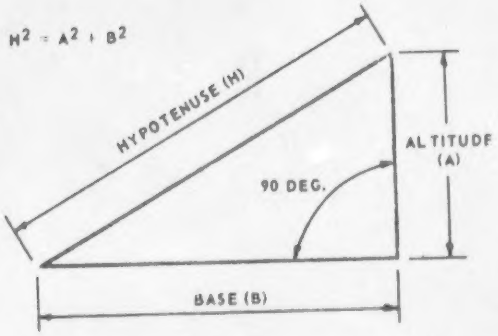

$H^2 = A^2 + B^2$
HYPOTENUSE (H)
ALTITUDE (A)
90 DEG.
BASE (B)

Fig. 9-5. Mathematical solution of a right triangle.

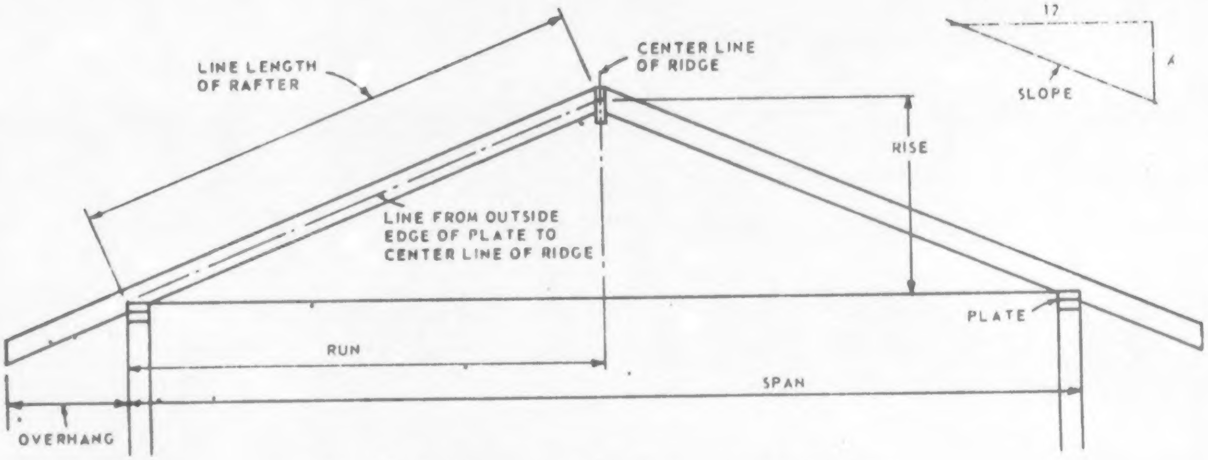

LINE LENGTH OF RAFTER
CENTER LINE OF RIDGE
12
A
SLOPE
RISE
LINE FROM OUTSIDE EDGE OF PLATE TO CENTER LINE OF RIDGE
PLATE
RUN
SPAN
OVERHANG

Fig. 9-6. Basic terms and dimensions used in rafter layout.

In rafter layout, the base of the right triangle is called the run. It is measured from the outside of the plate to the center of the ridge. The altitude or rise is the total distance the rafter extends above the plate. Other layout terms and the relationship of the parts of the roof frame are illustrated in figure 9-6.

Slope and Pitch

Slope indicates the incline of a roof as a ratio of the vertical rise to the horizontal run. It is properly expressed as X distance in 12. For example: a roof that rises at the rate of 4 in. for each foot of run, is designated as having a 4 in 12 slope. A triangular symbol above the roof line in the architectural plans is used to convey this information. The slope of a roof is sometimes called the "cut of the roof".

Pitch indicates the incline of the roof as a ratio of the vertical rise to the span (twice the run). It is expressed as a fraction. For example: if the total roof rise was 4 ft. and the total span was 24 ft., the pitch would be 1/6.

The run of a hip-valley cripple rafter will be equal to the side of a square, figure 9-38, the size of which is determined by the length of the plate between the hip and valley rafter. Use this distance and lay out the cripple, in the same manner used for a common rafter. Shorten each end by an amount equal to half the 45 deg. thickness of the hip and valley rafter stock. Now lay out and mark the side cuts, following the same procedure used for hip and valley jacks. Side cuts, required on each end, form parallel planes.

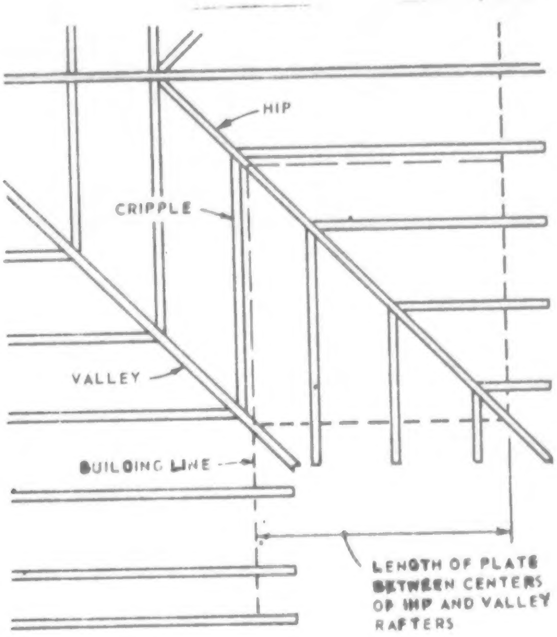


Fig. 9-38. The run of a hip-valley cripple jack is equal to the length of the wall plate.

Roof Truss Construction

A truss is a framework that is designed to carry a load between two or more supports. The principle used in its design is based on the rigidity of the triangle. Triangular shapes are built into the frame in such a way that the stresses of the various parts are parallel to the members making up the structure.

Roof trusses are frames that carry the roof and ceiling surfaces. They rest on the exterior walls and span the entire width of the structure. Since no load bearing partitions are required, more freedom in the planning and division of interior space is possible. They permit larger rooms without extra beams and supports. Another advantage which may reduce labor costs, is the opportunity to apply surface materials to outside walls, ceilings, and floors before partitions are constructed.

There are many types and configurations of roof trusses. One commonly used in residential construction is the W or Fink truss illustrated in figure 9-47. Trusses should always be constructed according to designs developed from engineering data. There are several sources for such material which usually includes not only detailed construction drawings, but also specifications concerning materials and fasteners. Tables listing the exact dimensions of the various members and suggested material lists, figure 9-48, will be helpful to the builder.

Roof trusses must be made of structurally sound lumber and assembled with carefully fitted joints. Although the carpenter is seldom required to determine the sizes of truss members or the type of joints, he should have sufficient understanding of their design to appreciate the necessity of first-class workmanship in their construction.

Trusses are pre-cut and assembled at ground level and then raised into position as a unit. Spacing of 24 in. O.C. is commonly used. However, 16 in. O.C. and other spacing may be required in some designs. When the truss is in position and loaded, there will be a slight sag. To compensate for this, the lower member (called the bottom chord) is raised slightly during fabrication of the unit. This adjustment is called camber and is measured at the mid-point of the span. A standard truss, 24 feet long, will usually require about 1/2 in. of camber.

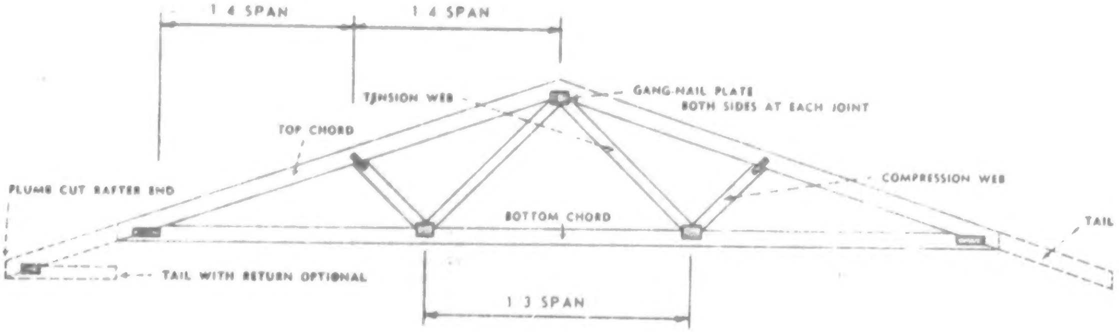
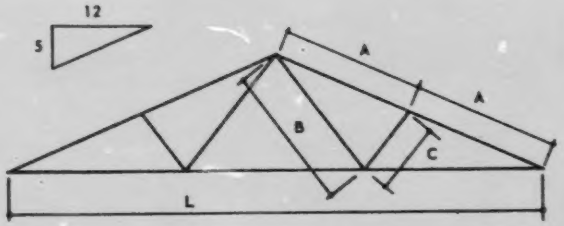


Fig. 9-47. Standard W or Fink truss commonly used in residential construction.

SPAN L	DIMENSIONS			DESIGN STRESSES					
	A	B	C	U_1	U_2	L_1	L_2	V_1	D_1
20'-0"	5'-5"	5'-3⅝"	2'-7⅝"	1756	1450	1614	1472	430	430
22'-0"	5'-11½"	5'-10 1/16"	2'-10 13/16"	1932	1595	1775	1619	473	473
24'-0"	6'-6"	6'-4 7/16"	3'-2"	2108	1740	1936	1766	516	516
26'-0"	7'-0½"	6'-10⅞"	3'-5¼"	2282	1885	2097	1913	559	559
28'-0"	7'-7"	7'-5¼"	3'-8 7/16"	2459	2030	2258	2060	602	602
30'-0"	8'-1½"	7'-11 11/16"	3'-11⅝"	2634	2175	2420	2207	645	645
32'-0"	8'-8"	8'-6 1/16"	4'-2 13/16"	2810	2320	2581	2354	688	688

Span	LUMBER				
	2" x 6"		2" x 4"		Total F.B.M.
	No.	Length	No.	Length	
20'-0"	2	12'-0"	2 2	12'-0" 10'-0"	53
22'-0"	2	14'-0"	2 2	14'-0" 10'-0"	60
24'-0"	2	14'-0"	2 2	14'-0" 12'-0"	63
26'-0"	2	16'-0"	2 2	16'-0" 12'-0"	70
28'-0"	2	16'-0"	2 2	16'-0" 14'-0"	73
30'-0"	2	18'-0"	2 2	18'-0" 14'-0"	79
32'-0"	2	20'-0"	2 2	18'-0" 14'-0"	83

HARDWARE		
No.	Item	Size
11	Split Rings	2½" Diam.
2	Trip-L-Grip	Type A
1	Bolt	½" x 7½"
2	Bolts	½" x 6"
4	Bolts	½" x 4"
14	Washers	½"



LUMBER--Lumber shall be of a good grade of sufficient quality to permit the following allowable unit stresses:
c = 900#/□" Compression parallel to grain.
f = 900#/□" Extreme fiber in bending.
E = 1,600,000#/□" Modulus of elasticity.

CONNECTORS--Timber connectors shall be 2-1/2" diameter split rings and Trip-L-Grip framing anchors.

BOLTS--Bolts shall be 1/2" diameter machine bolts with 2" x 2" x 1/8" plate washers, 2-1/8" diameter cast or malleable iron washers, or ordinary cut washers.

DIMENSIONS--Dimensions shown will provide approximately 1/2" camber at bottom chord panel points. Utilize full uncut length of bottom chord pieces by increasing the spacing of connectors in the splice.

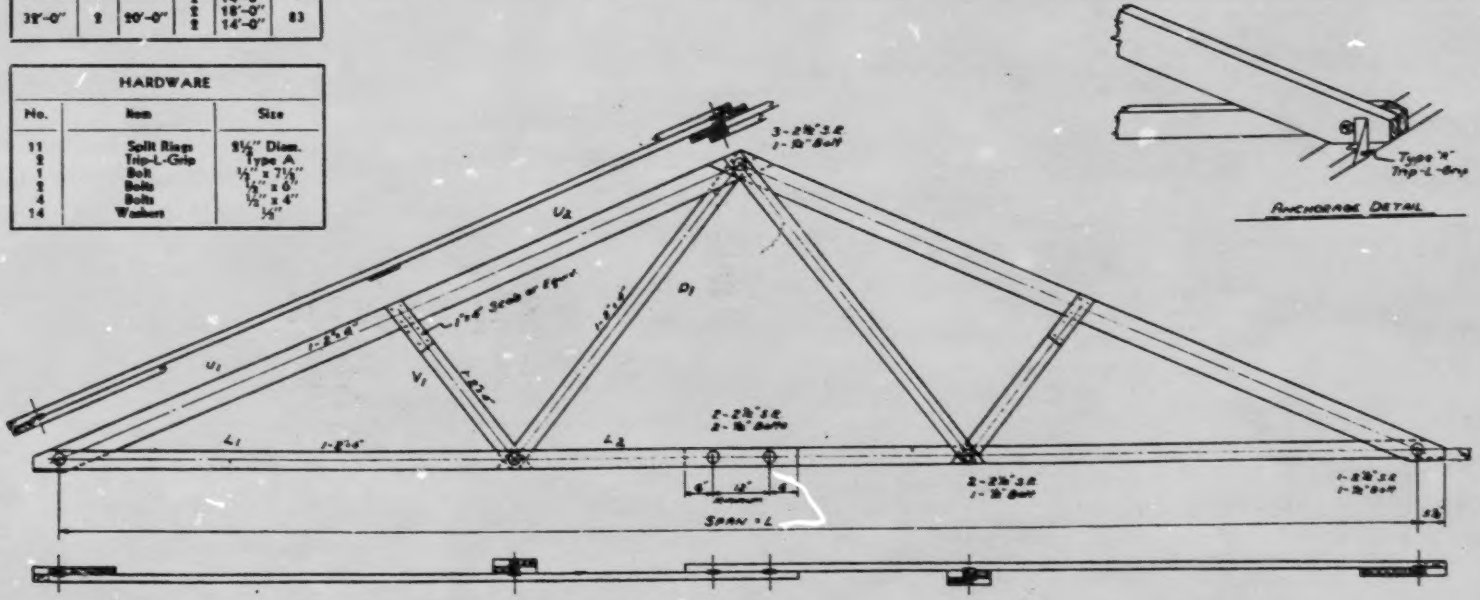

Type "A" Trip-L-Grip
ANCHORAGE DETAIL
3-2⅝" S.R.
1-½" Bolt
U2
U1
1-2"x6"
1-2"x4" Scab or Equiv.
1-2"x4"
D1
V1
1-2"x4"
L1
1-2"x6"
L2
2-2⅝" S.R.
2-½" Bolts
6"
12"
6"
2-2⅝" S.R.
1-½" Bolt
1-2⅝" S.R.
1-½" Bolt
SPAN = L
5½"

Fig. 9-48. Detail sheet of a truss designed for a roof slope of 5 in 12. (Timber Engineering Co.)

Roofing Materials

Types of Material

Materials used for sloping roofs include asphalt, wood, and mineral fiber shingles; slate and tile. Sheet materials such as roll roofing, galvanized iron, aluminum, and copper are somtimes used.

For flat roofs and low-sloped roofs, a membrane system is used. It consists of a continuous watertight surface, usually obtained through buildup roofs or seamed metal sheets. Built-up roofs are fabricated on the job by laminating roofing felts with asphalt or coal tar pitch and then coating the surface with crushed stone or gravel. Metal roofs of this type are assembled from flat sheets with a special seam that is soldered or sealed with special compounds to insure watertightness.

The selection of roofing materials is influenced by such factors as; the initial cost, maintenance costs, durability, and appearance. The slope of the roof limits the selection. Low-sloped roofs require a more watertight system than steep roofs, figure 10-2. Materials such as tile and slate require heavier roof frames. Local building codes may prohibit the use of certain materials because of the fire hazard or because they will not resist the high winds or other elements prevalent in a certain locality.

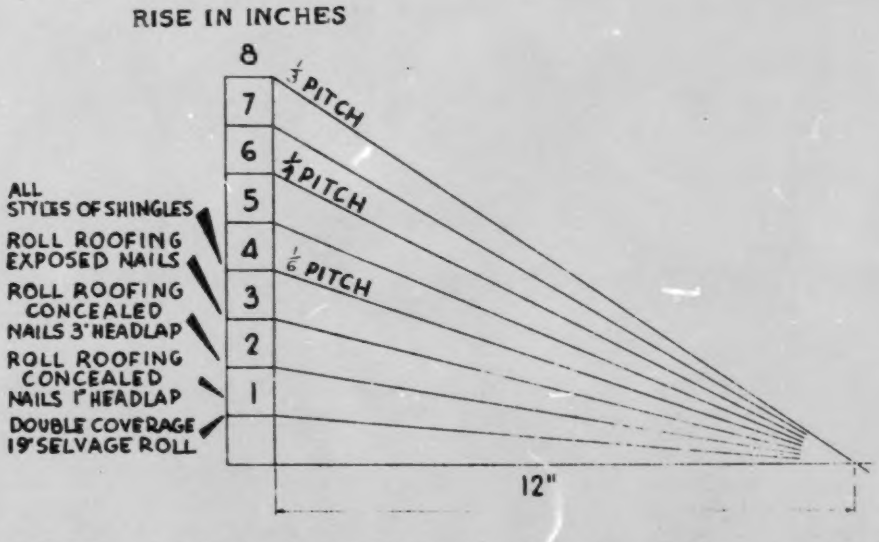

RISE IN INCHES
8
7
6
5
4
3
2
1
1/3 PITCH
1/4 PITCH
1/6 PITCH
ALL STYLES OF SHINGLES
ROLL ROOFING EXPOSED NAILS
ROLL ROOFING CONCEALED NAILS 3" HEADLAP
ROLL ROOFING CONCEALED NAILS 1" HEADLAP
DOUBLE COVERAGE 19" SELVAGE ROLL
12"

Fig. 10-2. Slope of roof limits the range of materials that can be used. The portion of the individual units (shingles) exposed to the weather must be reduced on low-sloped roofs.

Roofing Terms

Slope and pitch have already been defined. Several other terms commonly used include:

Square: Roofing materials are estimated and sold by the square. This is the amount of a given type of material needed to provide 100 sq. ft. of finished roof surface.

Coverage: This indicates the amount of weather protection provided by the overlapping of the shingles. Depending on the type of material and method of application, the shingles may furnish one (single coverage), two (double coverage) or even three (triple coverage) thicknesses of material on the roof.

Exposure: The shortest distance in inches between the edges of adjacent courses measured at right angles to the ridge.

Head Lap: The shortest distance in inches from the lower edge of an overlapping shingle or sheet, to the roof deck, figure 10-3.

Side Lap: The shortest distance in inches which horizontally adjacent elements of roofing overlap each other.

Shingle Butt: The lower exposed edge of shingle.

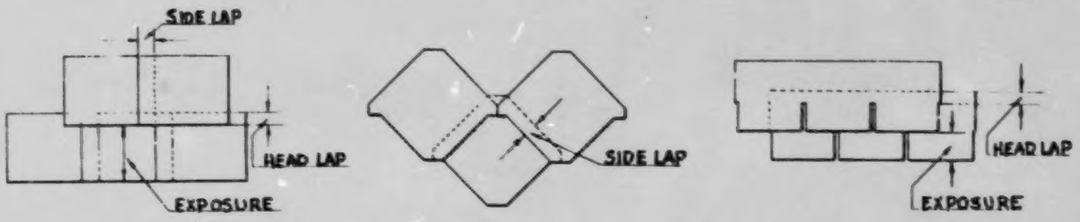


Fig. 10-3. Terms used in the application of roofing materials.

Preparing the Roof Deck

The roof sheating should be smooth, securely attached to the frame, and provide an adequate base to receive and hold the roofing nails and fasteners. All types of shingles can be applied over solid sheathing. Spaced sheathing is sometimes used for wood shingles. When solid boards are used for sheathing, they should not be over 6 in. wide.

It is also important that the attic space be properly ventilated to minimize condensation of moisture after the building is completed and ready for use. Sometimes moisture vapor from the lower stories, rising to the attic, will be chilled below its dew point and will cindense on the underside of the roof deck, causing sheathing boards to warp and buckle. To avoid this, louvered openings should be constructed high up under the eaves in the gable ends or at such locations as will insure adequate ventilation. Louvers should have a total effective area equivalent to 1/2 sq. in. per square foot of attic space.

Inspect the roof deck to see that nailing patterns are complete and that there are no protruding nails. Joints should be smooth and free of sharp edges that might cut through the roofing materials. Repair large knot holes (over 1" diameter) by covering with a piece of sheet metal. Clean the roof surface of any chips or other scrap material.

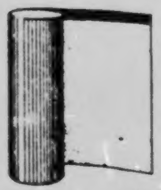
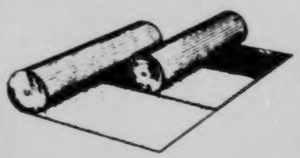
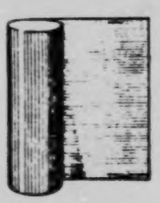
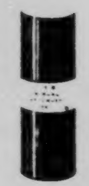
Strip Shingles

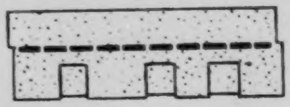
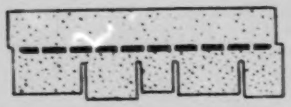
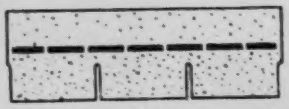
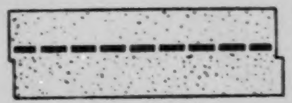
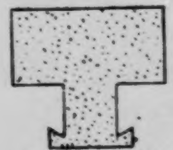
On small roofs, strip shingles may be laid starting at either end. When the roof surface is over 30 ft. in length, it is usually best to start at the center and work both ways from a line perpendicular to the eaves and ridge. Asphalt shingles will vary slightly in length (about plus or minus 1/4 in. in a 36 in. strip) and there may be some variations in width. Thus to control the proper placement so shingles will be accurately aligned horizontally and vertically, chalk lines should be used.

When making the application from the center of the roof toward the ends, snap a number of chalk lines between the eaves and ridge to serve as reference marks for starting each course. Space them according to the type of shingle and laying pattern. These lines are used in the same way that the rake edge of the roof is used when the application is started at the roof end as shown in the illustrations. The shingles do not need to be cut. Instead, full shingles are sligned with the chalk lines to form the desired pattern.

Chalk lines, parallel to the eaves and ridge, will be helpful in maintaining straight horizontal lines along the butt edge of the shingle. Usually, only about every fifth or sixth course should be checked in this way when the shingles are skillfully applied. Inexperienced workers may need to set up chalk lines for every second or third course.

Fig. 10-4. General specifications and installation data for common asphalt roofing products. (Asphalt Roofing Manufacturers Assoc.)

PRODUCT	Approximate Shipping Weight		Sqs. Per Package	Length	Width	Side or End Lap	Top Lap	Exposure	Underwriters' Listing
	Per Roll	Per Sq.							
 Mineral Surface Roll	75# to 90#	75# to 90#	One	36' 38'	36" 36"	6"	2" 4"	34" 32"	C
		Available in some areas in 9/10 or 3/4 Square rolls.							
 Mineral Surface Roll Double Coverage	55# to 70#	55# to 70#	One Half	36'	36"	6"	19"	17"	C
 Coated Roll	50# to 65#	50# to 65#	One	36'	36"	6"	2"	34"	None
 Saturated Felt	60# 60# 60#	15# 20# 30#	4 3 2	144' 108' 72'	36" 36" 36"	4" to 6"	2"	34"	None

PRODUCT	Configuration	Per Square			Size		Exposure	Underwriters' Listing
		Approximate Shipping Weight	Shingles	Bundles	Width	Length		
Wood Appearance Strip Shingle More Than One Thickness Per Strip  Laminated or Job Applied	Various Edge, Surface Texture & Application Treatments	285# to 390#	67 to 90	4 or 5	11-1/2" to 15"	36" or 40"	4" to 6"	A or C - Many Wind Resistant
Wood Appearance Strip Shingle Single Thickness Per Strip 	Various Edge, Surface Texture & Application Treatments	Various 250# to 350#	78 to 90	3 or 4	12" or 12-1/4"	36" or 40"	4" to 5-1/8"	A or C - Many Wind Resistant
Self-Sealing Strip Shingle 	Conventional 3 Tab	205#-240#	78 or 80	3	12" or 12-1/4"	36"	5" or 5-1/8"	A or C - All Wind Resistant
	2 or 4 Tab	Various 215# to 325#	78 or 80	3 or 4	12" or 12-1/4"	36"	5" or 5-1/8"	
Self-Sealing Strip Shingle  No Cut Out	Various Edge and Texture Treatments	Various 215# to 290#	78 to 81	3 or 4	12" or 12-1/4"	36" or 36-1/4"	5"	A or C - All Wind Resistant
Individual Look Design  Basic Design	Several Design Variations	180# to 250#	72 to 120	3 or 4	18" to 22-1/4"	20" to 22-1/2"		C - Many Wind Resistant

Nailing and Fastening

Nails used to apply asphalt roofing must have a large head (3/8 in. to 7/16 in. dia.) and a sharp point, figure 10-8. Most manufacturers recommend 11 or 12 ga. galvanized steel nail with barbed shanks. Aluminum nails are also used. The **length** should be sufficient to penetrate nearly the full thickness of the sheathing.

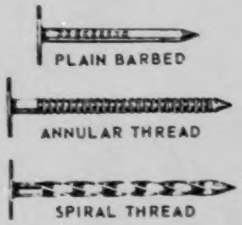


Fig. 10-8. Nails used for asphalt shingles. Use 1 1/4 in. nails for new roofs, and 1 3/4 in. nails for reroofing. Average shingles will require 480 nails per square or 2 1/4 lbs. of 1 1/4 in. size – 2 3/4 lbs. of 1 3/4 in. size.

The number of nails and correct placement are both vital factors in proper application of a roofing material. For three-tab square-butt shingles, use a minimum of 4 nails per strip as shown in the application diagrams. Align each shingle carefully and start the nailing from the end next to the one previously laid and proceed across the shingle. This will prevent buckling. Drive nails straight so the edge of the head will not cut into the shingle. The nail head should be driven flush, not sunk into the surface. If for some reason the nail fails to hit solid sheathing--drive another nail in a slightly different location.

Starter Strip

The purpose of a starter strip is to back up the first course of shingles and fill in the space between the tabs. Use a strip of mineral surfaced roofing (9 in. or wider) of a weight and color to match the shingles. Apply the strip so it overhangs the drip edge slightly and secure it with nails spaced 3 to 4 in. above the edge. Space the nails so they will not be exposed at the cutouts between the tabs of the first course of shingles. Sometimes an inverted row of shingles is used instead of the starter strip.

First and Succeeding Courses

The first course is started with a full shingle. Succeeding courses are then started with either full or cut strips, depending upon the type of shingle and the laying pattern.

Three-tab square-butt shingle strips are commonly laid so the cutouts are centered over the tab in the course directly below, thus the cutouts in every other course will be exactly aligned as shown in figures 10-10, 10-11 and 10-12.

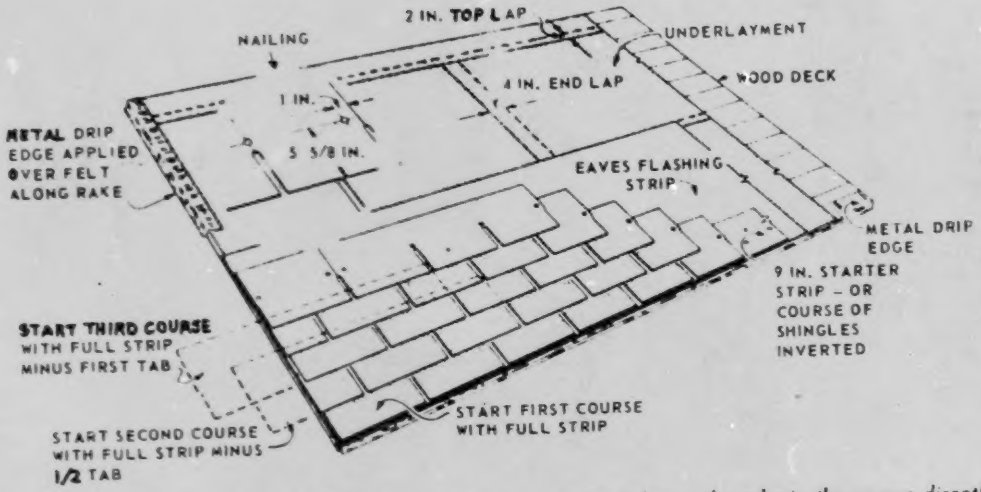

2 IN. TOP LAP
NAILING
UNDERLAYMENT
WOOD DECK
1 IN.
4 IN. END LAP
METAL DRIP EDGE APPLIED OVER FELT ALONG RAKE
5 5/8 IN.
EAVES FLASHING STRIP
METAL DRIP EDGE
9 IN. STARTER STRIP – OR COURSE OF SHINGLES INVERTED
START THIRD COURSE WITH FULL STRIP MINUS FIRST TAB
START FIRST COURSE WITH FULL STRIP
START SECOND COURSE WITH FULL STRIP MINUS 1/2 TAB

Fig. 10-10. Three-tab square butt shingles laid so the cutouts are centered over the tabs in the course directly below.

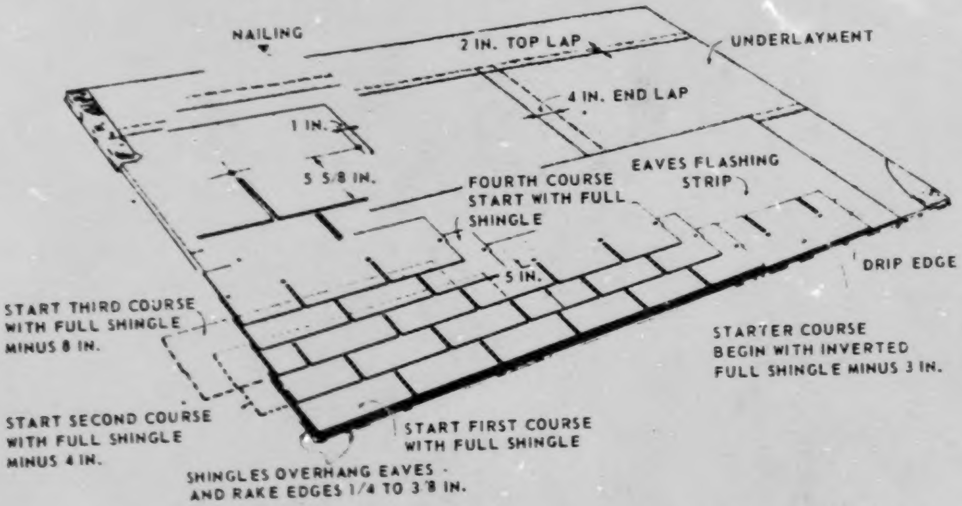

NAILING
2 IN. TOP LAP
UNDERLAYMENT
4 IN. END LAP
1 IN.
5 5/8 IN.
FOURTH COURSE START WITH FULL SHINGLE
EAVES FLASHING STRIP
DRIP EDGE
5 IN.
START THIRD COURSE WITH FULL SHINGLE MINUS 8 IN.
STARTER COURSE BEGIN WITH INVERTED FULL SHINGLE MINUS 3 IN.
START SECOND COURSE WITH FULL SHINGLE MINUS 4 IN.
START FIRST COURSE WITH FULL SHINGLE
SHINGLES OVERHANG EAVES AND RAKE EDGES 1/4 TO 3/8 IN.

Fig. 10-11. Three-tab square butt shingles laid with cutouts breaking joints on thirds.

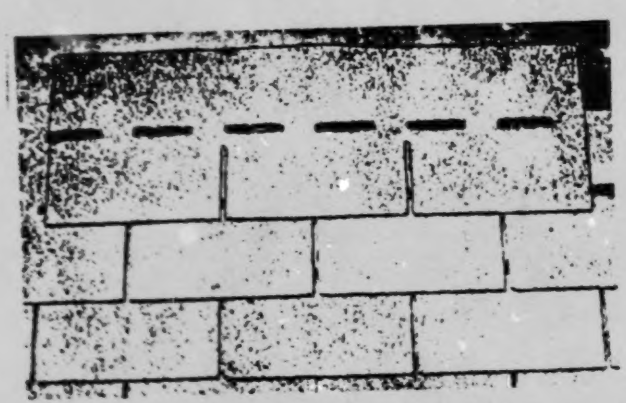


Fig. 10-12. Approved nailing pattern for three-tab square butt shingles. (Asphalt Roofing Manufacturers Assoc.)

Stack Flashing

Pipes projecting through the roof must be carefully flashed. Various prefabricated flanges are available for this purpose. Asphalt products can also be used successfully for the flashing.

The roofing is first applied up to where the stack projects. Shingles are cut and fitted around the stack, figure 10-17. A flange is then carefully cemented in place and the roof shingles laid over the top as shown. The flange must be large enough to extend at least 4 in. below, 8 in. above, and 6 in. on each side.

WHEN LAYING ASPHALT SHINGLES, IT'S A GOOD IDEA TO WEAR SOFT SOLED SHOES THAT WILL NOT DAMAGE THE SURFACE AND EDGE OF THE SHINGLES. ASPHALT PRODUCTS ARE EASY TO DAMAGE WHEN WORKED AT HIGH TEMPERATURES SO TRY TO AVOID LAYING THESE MATERIALS ON EXTREMELY HOT DAYS.

Hips and Ridges

Special hip and ridge shingles are usually available from the manufacturer. The special shingles can be easily made, however, by cutting pieces 9 in. by 12 in. from either square-butt shingle strips or mineral surfaced roll roofing that matches the color of the shingles.

After the shingles are cut, band them lengthwise in the center line. In cold weather, the shingle should be warmed before bending to prevent cracks and breaks. Begin at the bottom of the hips or one end of the ridge. Lap the units to provide a 5 in. exposure as illustrated in figure 10-18. Secure with one nail on each side, 5 1/2 in. back from the exposed end and 1 in. from the edge.

Metal ridge roll is not recommended for asphalt shingles since corrosion may discolor the roof.

Wind Protection

Shingles that are provided with factory applied adhesive under each tab are available for use in localities where high winds are frequent. After installation, only a few warm days are needed to thoroughly seal the tabs to the course below and thus prevent them from being blown up by strong winds. This precaution is especially important on low sloping roofs where it is easier for the wind to "get under" the shingles.

If regular shingles are used, the tabs can be cemented as shown in figure 10-19. Apply a spot of special tab cement about 1 in. square with a putty knife or caulking gun and then press the tab down. Avoid lifting the tab any more than necessary while applying the cement.

A variety of interlocking shingles are designed to provide resistance against strong winds. They are used for both new construction and reroofing. Details of the interlocking devices and methods of application vary considerably. Always study and follow the manufacturer's directions when installing all types of shingles.

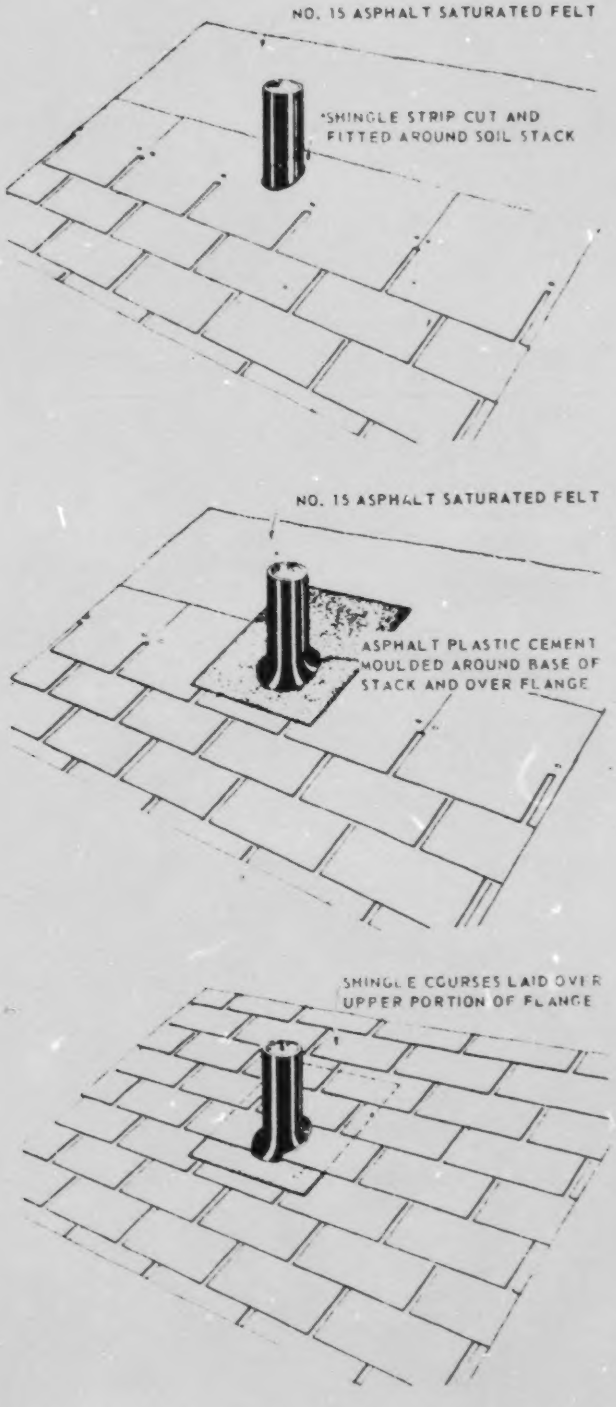

NO. 15 ASPHALT SATURATED FELT
SHINGLE STRIP CUT AND FITTED AROUND SOIL STACK
NO. 15 ASPHALT SATURATED FELT
ASPHALT PLASTIC CEMENT MOULDED AROUND BASE OF STACK AND OVER FLANGE
SHINGLE COURSES LAID OVER UPPER PORTION OF FLANGE

Fig. 10-17. Flashing vent stack. Top. Shingles laid up to stack and last course fitted. Center. Flange in place. Bottom. Shingles applied over flange.

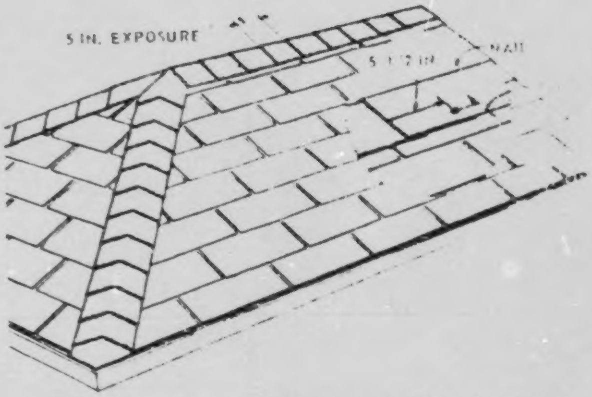

5 IN. EXPOSURE
5 1/2 IN.
NAIL

Fig. 10-18. Application of hip and ridge shingles

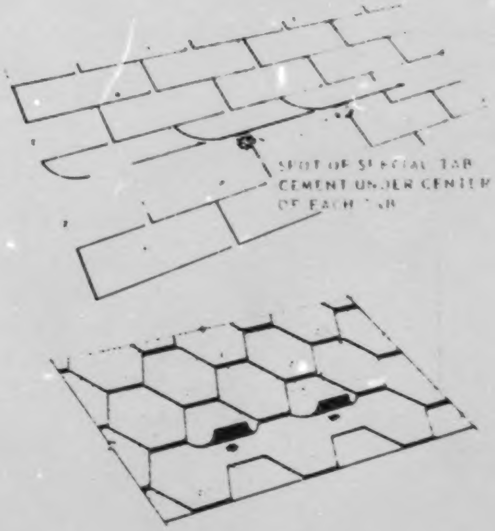

SPOT OF SPECIAL TAB CEMENT UNDER CENTER OF EACH TAB

Fig. 10-19. Asphalt shingle tabs may be cemented down for wind protection. Above. Square butt shingles. Below. Hexagonal shingles.

Individual Asphalt Shingles

Roof surfaces may be laid with an individual asphalt shingle. There are several sizes and designs available. One commonly used is 12 in. wide and 16 in. long. Several patterns can be used in its application, one of which is illustrated in figure 10-20. Follow the same procedure that was described for strip shingles. Horizontal and vertical chalk lines should be used to insure accurate alignment.

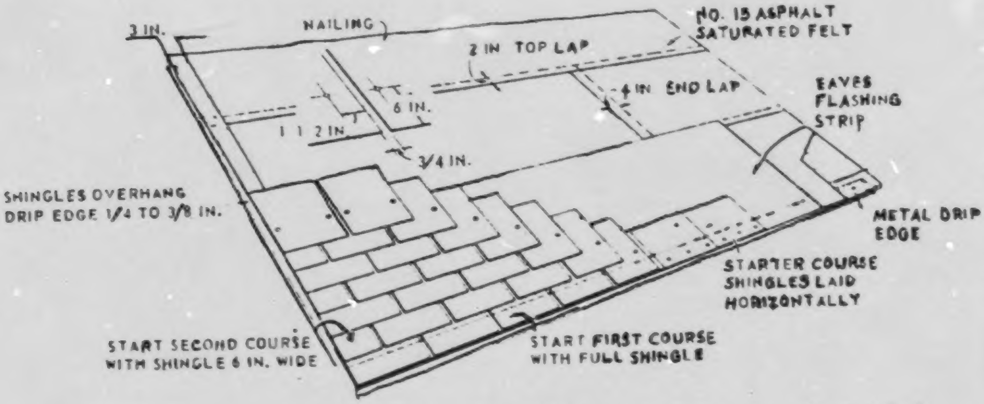

3 IN.
NAILING
NO. 15 ASPHALT SATURATED FELT
2 IN TOP LAP
4 IN END LAP
EAVES FLASHING STRIP
6 IN.
1 1 2 IN
3/4 IN.
SHINGLES OVERHANG DRIP EDGE 1/4 TO 3/8 IN.
METAL DRIP EDGE
STARTER COURSE SHINGLES LAID HORIZONTALLY
START SECOND COURSE WITH SHINGLE 6 IN. WIDE
START FIRST COURSE WITH FULL SHINGLE

Fig. 10-20. Application of giant individual asphalt shingles by the American method.

Low-Slope Roofs

When applying asphalt shingles to slopes less than 4 in 12, certain additional application procedures should be followed. Slopes as low as 2 in 12 can be made watertight and windtight if the installation includes:

1. A double thickness felt underlayment. Lap each course over the preceeding one 19 in., starting with a 19 in. strip.
2. In areas where the January daily average temperature is 25 deg. F. or less, cement the two felt layers together from the eave up the roof to a point 24 in. inside the interior wall line of the building. See figure 10-21.
3. Shingles provided with factory applied adhesive and manufactured to conform to the Underwriters Laboratories Standard for Class "C" Wind Resistant shingles, or, if "free" tab square-butt strips are used, cement all the tabs as previously described.
4. Follow application methods shown in figure 10-22.

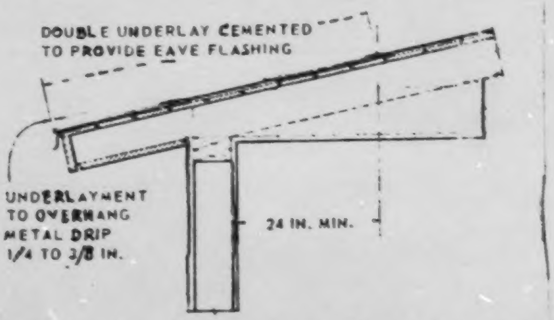

DOUBLE UNDERLAY CEMENTED TO PROVIDE EAVE FLASHING
UNDERLAYMENT TO OVERHANG METAL DRIP 1/4 TO 3/8 IN.
24 IN. MIN.

Fig. 10-21. Underlay plies cemented together to form eaves flashing for low-sloped roofs.

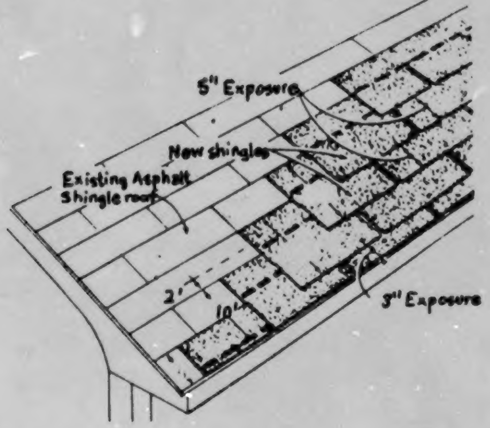


Fig. 10-23. Recommended application pattern over existing asphalt shingle roof. (Asphalt Roofing Manufacturers Assoc.)

The joint between a vertical wall and roof surface should be sealed in a reroofing application. First apply a strip of smooth roll roofing about 8 in. wide. Nail each edge firmly with a spacing of about 4 in. O.C. As the shingles are applied, asphaltic plastic cement is spread on the strip and the shingles are thoroughly bedded. To insure a tight joint, use a caulking gun to apply a final bead of cement between the ends of the shingles and the siding.

When old shingles are to be removed before applying a new roof, it is common practice to use a flat-bladed shovel as shown in figure 10-24. Both asphalt and wood shingles can be removed in this manner. A shovel can also be used to remove the old underlayment.

Fig. 10-24. Using a shovel to remove old asphalt shingles (Asphalt Roofing Manufacturers Assoc.)

Built-Up Roofing

A flat roof or a roof with very little slope must be covered with a watertight membrane. Most flat roofs today are covered with built-up roofing which, if properly installed, is quite durable. The components are delivered to the job. The roofing itself is constructed directly on the deck in a series of layers or plies.

On a wood deck, a layer of roofing felt is first nailed in place with galvanized nails, figure 10-25. Each succeeding layer is then mopped in place with hot asphalt or hot coal tar pitch. The top layer is coated and covered with a layer of gravel, crushed stone or marble chips which provides a weathering surface and **may** also improve the appearance. This mineral covering is usually applied at the rate of 300 to 400 lb. per 100 sq. ft.

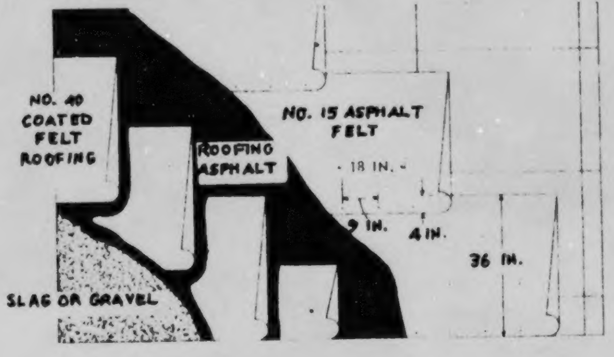

NO. 40 COATED FELT ROOFING
ROOFING ASPHALT
NO. 15 ASPHALT FELT
18 IN.
9 IN.
4 IN.
36 IN.
SLAG OR GRAVEL

Fig. 10-25. Construction of built-up roofing. (Ruberoid Co.)

Built-up roofs for residential structures are normally 3 or 4 plies (layers) and are limited to a slope of not over 2 in 12. Asphalt moppings are used on sloping roofs while coal-tar pitch, which has a "cold flow" must be limited to flat surfaces. A metal gravel stop, preferably made of copper, is fastened to the edge of the roof deck to serve as a trim member and keep the gravel and pitch in place, figure 10-26.

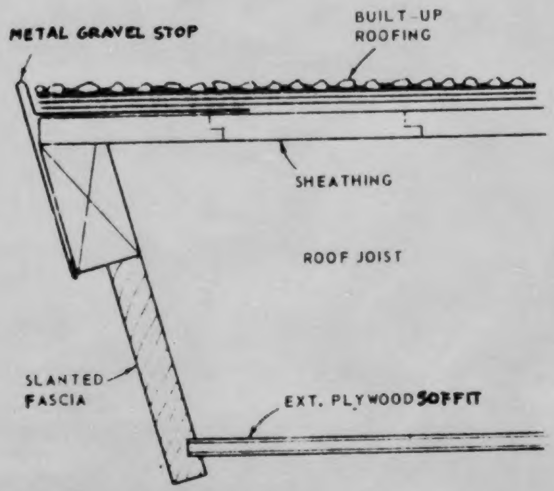

METAL GRAVEL STOP
BUILT-UP ROOFING
SHEATHING
ROOF JOIST
SLANTED FASCIA
EXT. PLYWOOD SOFFIT

Fig. 10-26. Section through edge of flat roof overhang show-

When a leak occurs in a built-up roof, flashings at parapet walls, chimneys, and vents should be inspected carefully, because the first roof failures usually occur at these locations. Bituminous flashings are made of saturated felt and flashing cement, figure 10-27. Flashing cement should be forced behind the felt if it has separated from the wall at the upper edge, and the edge sealed with a strip of bituminous-saturated cotton fabric 4 in. wide, embedded and coated with flashing cement.

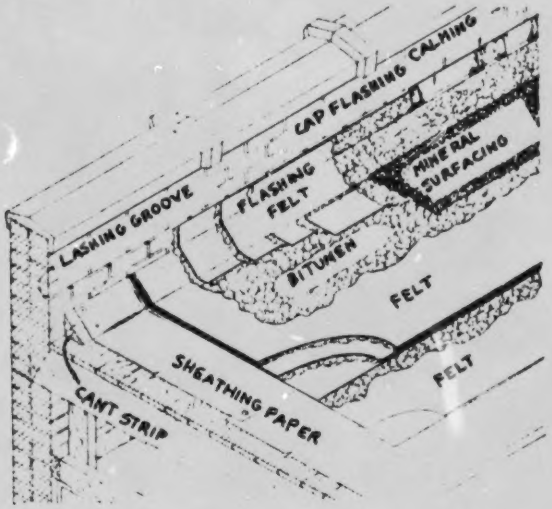


Fig. 10-27. Flashing construction for built-up roofs.

Bare spots on a built-up roof where the mineral surfacing is not not properly embedded should be repaired. First clean the area, apply a heavy coating of hot asphalt and then spread more gravel or slag. Felts which have disintegrated should be cut away and replaced with new felt. The new felt should be mopped in place, allowing at least one additoonal layer of felt to extend not less than 6 in. beyond the other layers.

Wood Shingles

Wood shingles have been used for many years in residential construction. A disadvantage is that wood shingles, unless treated, have little resistance to fire. Building codes often prohibit their use. Since wood weathers to a soft, mellow color after exposure, wood shingles provide an appearance that is desired by many home owners. When properly installed, they also provide a very durable roof.

Wood shingles are made from western red cedar, redwood, and cypress, all of which are highly decay resistant. They are taper sawed and graded No. 1, No. 2, and No. 3, plus a utility grade. The best grade is cut in such a way that the annular rings are perpendicular to the surface. Butt ends vary in thickness from 1/2 to 3/4 in. as shown in figure 10-28. Wood shingles are manufactured in random widths and in lengths of 16, 18, and 24 inches. They are packaged in bundles; four bundles containing enough shingles to cover one square (100 sq. ft.) when a standard application is made.

Grade	Length	Thickness (at Butt)	No. of Courses Per Bundle	Bdls Cartons Per Square	Shipping Weight	Description
No. 1 BLUE LABEL	16" (Fivex) 18" (Perfections) 24" (Royals)	40" 45" 50"	20/20 18/18 13/14	4 bdls 4 bdls 4 bdls	144 lbs. 158 lbs. 192 lbs.	The premium grade of shingles for roofs and side walls. These top grade shingles are 100% heart wood. 100% clear and 100% edge grain
No. 2 RED LABEL	16" (Fivex) 18" (Perfections) 24" (Royals)	40" 45" 50"	20/20 18/18 13/14	4 bdls 4 bdls 4 bdls	144 lbs. 158 lbs. 192 lbs.	A good grade for all applications. Not less than 10" clear on 16" shingles. 11" clear on 18" shingles and 15" clear on 24" shingles. Flat grain and limited sapwood are permitted in this grade
No. 3 BLACK LABEL	16" (Fivex) 18" (Perfections) 24" (Royals)	40" 45" 50"	20/20 18/18 13/14	4 bdls 4 bdls 4 bdls	144 lbs. 158 lbs. 192 lbs.	A utility grade for economy applications and secondary buildings. Not less than 6" clear on 16" and 18" shingles. 10" clear on 24" shingles
No. 1 or No. 2 REBUTTED-REJOINTED	16" (Fivex) 18" (Perfections) 24" (Royals)	40" 45" 50"	33/33 28/28 13/14	1 carton 1 carton 4 bdls.	60 lbs. 60 lbs. 192 lbs.	Same specifications as above but machine trimmed for exactly parallel edges with butts sawn at precise right angles. Used for sidewall application where tightly fitting joints between shingles are desired. Also available with smooth sanded face
No. 4 UNDER-COURSING	16" (Fivex) 18" (Perfections)	40" 45"	14/14 or 20/20 14/14 or 18/18	2 bdls 2 bdls 2 bdls 2 bdls.	60 lbs. 72 lbs. 60 lbs. 79 lbs.	A utility grade for undercoursing on double coursed sidewall applications or for interior accent walls

Fig. 10-28. Wood shingles. Grades and specifications.
(Red Cedar Shingle and Handsplit Shake Bureau)

The exposure of wood shingles is dependent on the slope of the roof. When the slope is 5 in 12 or greater, standard exposures of 5, 5 1/2, and 7 1/2 inches are used for 16, 18, and 24 inch sizes respectively. On roofs with lower slopes, the exposure should be reduced to 3 3/4, 4 1/4, and 5 3/4 in. which will provide a minimum of four layers of shingles over the entire roof area. In any type of construction there should be a minimum of three layers at any given point to insure complete protection against heavy wind-driven rain.

Sheathing

Solid sheathing for wood shingles may consist of matched or unmatched 1 in. boards, shiplap, or plywood. Open or spaced sheathing, figure 10-29, is sometimes used because it costs less and permits the shingles to dry out quickly. One reason for using solid sheathing is to gain the added insulation and resistance to infiltration that such a deck offers.

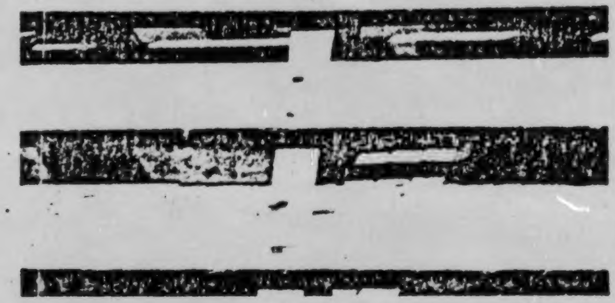
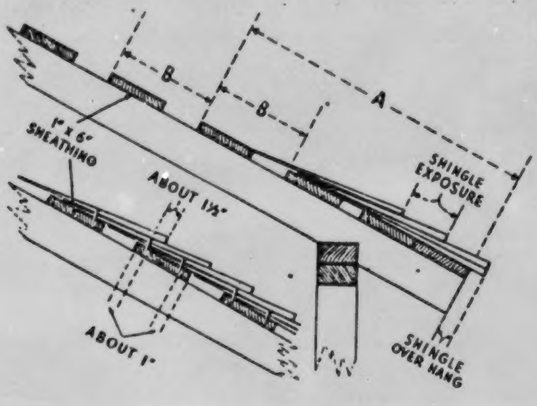


Fig. 10-29. Open or spaced sheathing may be used for wood shingles or shakes. (Western Wood Products)

One method of applying spaced roof sheathing is to space 1 by 3 in., 1 by 4 in. or 1 by 6 in. boards the same distance apart as the anticipated shingle exposure and to nail each course of shingles to a separate board. Another is to use 1 by 6 in. lumber as sheathing boards with two courses of shingles nailed to each one. Figure 10-30 shows the recommended sheathing placement and spacing for various shingle exposures when the latter method is used.



SHEATHING SIZE	SHINGLE EXPOSURE	COLUMN 4 (A) Distance between upper edge of arbitrarily placed key sheathing board and lower edge of starting sheathing board at the eave	COLUMN 2 (B) Proper spacing of sheathing boards (upper edge to upper edge) below and above the key sheathing board indicated in Column 1.
1 x 6"	3¾"	27½"	7½" Edge to Edge
	4¼"	30½"	8½" Edge to Edge
	4½"	32 "	9 " Edge to Edge
	5 "	30½"	10 " Edge to Edge

EXAMPLE—4½" shingle exposure, 1 x 6 sheathing, and 1½" shingle overhang. Apply first sheathing board where desired at lower edge of roof, then attach upper edge of 1 x 6 sheathing board a distance of 32" (Column 1) from lower edge of first sheathing board at eave-line. Next, nail sheathing boards 9" apart (upper edge to upper edge as shown in Column 2) below this board until tight sheathing is encountered and above this board until peak or ridge of roof is reached. Starting course of shingles should be given an overhang of 1½"; shingles should be nailed 1½" above butt line of next course to be applied and nails should strike sheathing about 1" from [illegible] edge.

Fig. 10-30. *Spacing of 1 x 6 in. sheathing boards for various shingle exposures.*

Underlayment

Normally an underlayment is not used for wood shingles, when applied on either spaced or solid sheathing. If it is desirable to use roofing paper to prevent air infiltration, the roof may be covered with rosin-sized building paper or "dry" unsaturated felts. Saturated building paper is usually not recommended because of the condensation trouble it may cause.

Flashing

In areas where outside temperatures drop to 0 deg. F. or colder and there is a possibility of ice forming along the eaves and causing water to back up, an eaves flashing strip is recommended. Follow the same procedure for making the installation as described for asphalt shingles.

The importance of using good materials for valleys and flashings cannot be overemphasized. Materials used for this purpose include tin plate, lead-clad iron, galvanized iron, lead, copper and aluminum sheets.

If galvanized iron (mild steel coated with a layer of zinc) is selected, 24 or 26 ga. metal should be used. Tin, or galvanized sheets with less than 2 oz. of zinc per square foot, should be painted on both sides with white lead and oil paint and allowed to dry before being used. When making bends, care should be taken not to crack the zinc coating. On roofs of 1/2 pitch or steeper, the valley sheets should extend up on both sides of the center of the valley for a distance of at least 7 in. On roofs of less pitch, wider valley sheets should be used, with a minimum extension of at least 10 in. on both sides, figure 10-31. The open portion of the valley is usually about 4 in. wide and should gradually increase in width toward the lower end.

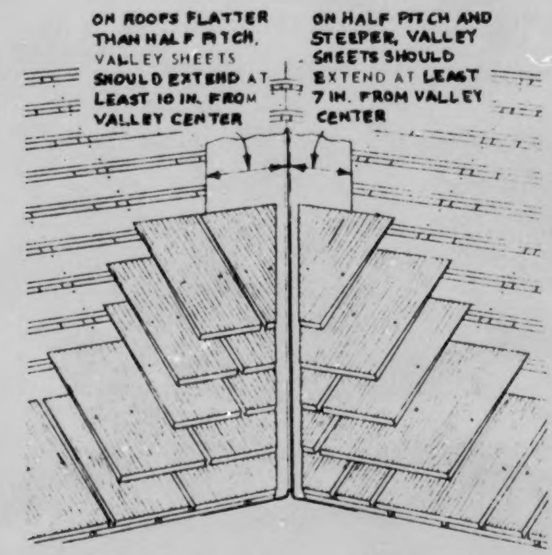

ON ROOFS FLATTER THAN HALF PITCH, VALLEY SHEETS SHOULD EXTEND AT LEAST 10 IN. FROM VALLEY CENTER
ON HALF PITCH AND STEEPER, VALLEY SHEETS SHOULD EXTEND AT LEAST 7 IN. FROM VALLEY CENTER

Fig. 10-31. Valley construction for wood shingles. (Red Cedar Shingle and Handsplit Shake Bureau)

Mineral Fiber Shingles

Mineral fiber shingles (also called asbestos cement shingles) are manufactured from asbestos fiber and Portland cement. They are formed in molds under high pressure and provide a finished product that is immune to rot and decay, unharmed by exposure to salt air, unaffected by ice or snow, and fireproof because they contain nothing that will burn.

Mineral fiber shingles are available in a variety of colors and textures and may be obtained in rectangular, square, and hexagonal shapes; in single or multiple units, figure 10-47. They are sold by the square, and are equally well adapted for use on new buildings

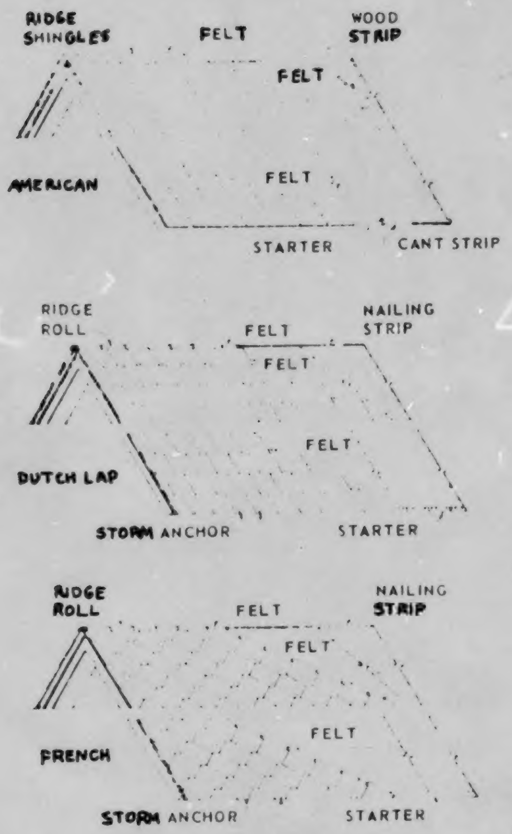

RIDGE SHINGLES
FELT
WOOD STRIP
FELT
AMERICAN
FELT
STARTER
CANT STRIP
RIDGE ROLL
FELT
NAILING STRIP
FELT
DUTCH LAP
FELT
STORM ANCHOR
STARTER
RIDGE ROLL
FELT
NAILING STRIP
FELT
FRENCH
FELT
STORM ANCHOR
STARTER

Fig. 10-47. ***Types*** *of mineral fiber* ***shingles. Minimum slope*** *4 in 12 for American, 5 in 12 for Dutch lap and* ***hexagonal.***

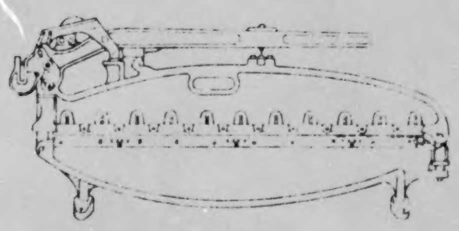


Fig. 10-48. ***A special cutter for mineral fiber shingles.***

or over old roofs. On old roofs, the new shingles can usually be applied right over the old roof, saving the co[illegible] of removing the old shingles and giving the roof the added insulation of the old roofing.

Because the mineral fiber material is rigid and hard, nail holes are prepunched during the manufacturing process. Eave starter strips, hip and ridge shingles, and ridge rolls are prefabricated to further simplify the application. Shingles should be installed with galvanized needlepoint nails. For new roofs, use 1 1/4 in. nails. When reroofing over old shingles, use 2 in. nails.

Special equipment is required to cut the material. Dealers handling mineral fiber products will usually have several shingle cutters on hand for the use of customers, figure 10-48. They cut the shingles quickly, accurately and neatly; and they also have a punch for forming nail holes where extra holes are required.

If a cutter is not available, asbestos shingles can be cut by hand. Use an old chisel, a drift punch, or the blade of the hatchet. Score the shingle with the tool being drawn along a straightedge. After scoring, place the shingle over a solid piece of wood and break along the scored line, figure 10-49. Irregular cuts or round holes are made by punching holes along the line of the cut and breaking out the piece which is to be discarded. There is a punch on the shingle cutter for punching additional holes, or they may be drilled or punched with a drift punch or other suitable pointed tool. A drift punch is recommended because it will punch a clean hole without splitting the material.

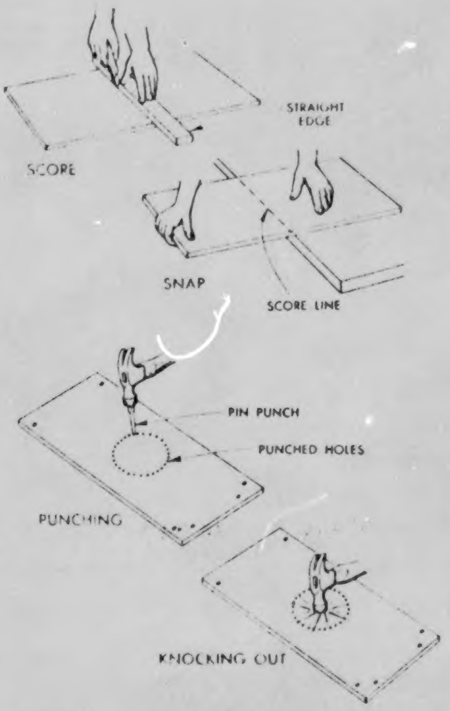


Fig. 10-49. Forming mineral fiber products by hand. Above. Score and snap method. A carbide tipped blade works best. Below. Making interior cutouts. (Mineral Fiber Products Bureau)

Storing Shingles

While still packed in bundles, whether in the yard or on the job, mineral fiber shingles should be kept dry. Moisture trapped between bundled shingles may cause discoloration due to efflorescence, or what ordinarily is known as "blooming". If it is necessary to use outdoor storage, stack the shingles on planks and use roofing felt, waterproof paper or a tarpaulin for cover.

Application of Mineral Fiber Shingles

It is important that the roof deck be in proper condition to receive the shingles. The lumber should be well seasoned, dry and of uniform thickness. Tongue-and-groove 1 x 6 boards or plywood of adequate thickness is recommended. Nailheads must be driven down and any high spots or rough edges removed. A wood cant strip should be applied along the eaves, flush with the lower edge, to give proper pitch for the shingles.

Attach a furring strip along each side of hips and ridges to provide a nailing base for the hip and ridge covering. The roof shingles are butted against these furring strips; therefore they must be the same thickness as the shingles. The furring strips should not be over 2 in. wide, so they will be covered by the ridge units, figure 10-50.

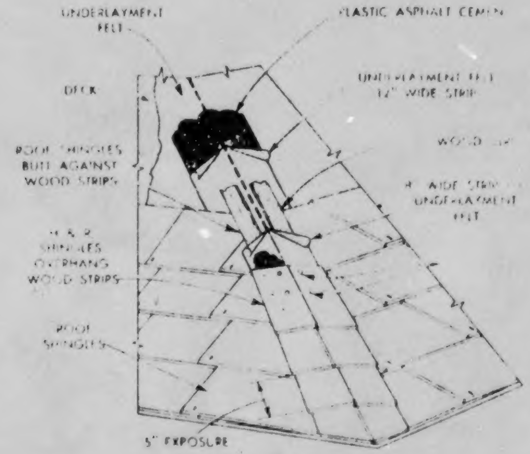

UNDERLAYMENT FELT
PLASTIC ASPHALT CEMENT
DECK
UNDERLAYMENT FELT 12" WIDE STRIP
WOOD STRIP
ROOF SHINGLES BUTT AGAINST WOOD STRIPS
WIDE STRIP UNDERLAYMENT FELT
H & R SHINGLES OVERHANG WOOD STRIPS
ROOF SHINGLES
5" EXPOSURE

Fig. 10-50. Hip and ridge construction. (Mineral Fiber Products Bureau)

On new work or on reroofing jobs where the old materials have been removed, the roof boards should be covered with one course of waterproof sheathing paper. Horizontal laps need not be over 2 in.; end laps should be 6 in. Hips, ridges, and valleys are covered with a 12 in. lap so double thickness will be assured at these points.

Flashing for Mineral Fiber Shingles

Care should be exercised in applying valley flashings. First, a corrosion resistant metal, such as copper or stainless steel, should be used for valleys when a mineral fiber roof is being put on. Do not use aluminum. Secondly, to insure a leakproof roof, the metal valley should extend out on the roof deck well beyond the edge of the overlapping shingles and well up under the shingles on both sides. Finally, shingles should be bedded down in a layer of asphalt cement for a distance of 6 in. back from the edge where the shingles end at the valley.

Galvanized Sheet Metal Roofing

Only galvanized sheets that are heavily coated with zinc (2.0 oz. per sq. ft.) are recommended for permanent-type construction. The sheets with lighter coatings of zinc are less durable and are likely to require painting every few years. On temporary buildings and in cases where the most economical construction is required, lighter metal can be used and will give satisfactory results if protected by paint.

Slope and Laps

Galvanized sheets may be laid on slopes as low as a 3 in. rise to the foot (1/8 pitch). If more than one sheet is required to reach the top of the roof, the ends should lap not less than 8 in. When the roof has a pitch of 1/4 or more, 4 in. end laps are usually satisfactory.

To make a tight roof, sheets should be lapped 1 1/2 corrugations at either side, figure 10-53. The wind is likely to drive rain water over single-corrugation lap joints. When using roofing 27 1/2 in. wide with 2 1/2 in. corrugations and 1 1/2 corrugation lap, each sheet covers a net width of 24 in. on the roof.

When 27 1/2 in. roofing is not available, sheets of 26 in. in width may be used. In laying the narrower sheets, every other one should be turned upside down. So laid, each alternate sheet laps over the two intermediate sheets. The 26 in. roofing with 2 1/2 in. corrugations cover a net width of 22 1/4 in. of roof.

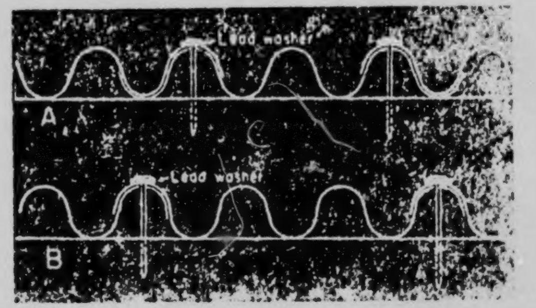


Fig. 10-53. Application of corrugated sheet metal ***roofing*** *Above. Sheets properly laid with 1 1/2* ***corrugation—*** *Below. Single-corrugation-lap not recommended.*

Sheathing and Nails

If 26 ga. sheets are used, supports may be 24 in. apart. If 28 ga. sheets are used, supports should be not more than 12 in. apart. The heavier gauge has no particular advantage advantage except its added strength, because the zinc coating is what gives this type roofing its durability.

For best results, galvanized sheets should be fastened with lead-headed nails or galvanized nails and lead washers. Nails properly located are driven only into tops of the corrugations. To avoid unnecessary corrosion, use nails specified by the manufacturer.

Tile Roofing

The most commonly used roofing tile are manufactured products consisting of molded, hardburned shale or mixtures of shale and clay. Metal tile is also available.

When well made, clay tile is hard, fairly dense and durable, and may be obtained in a variety of shapes and textures. Most roofing tile of clay is unglazed, although glazed tile is sometimes used. Typical tile roof application details are shown in figure 10-52.

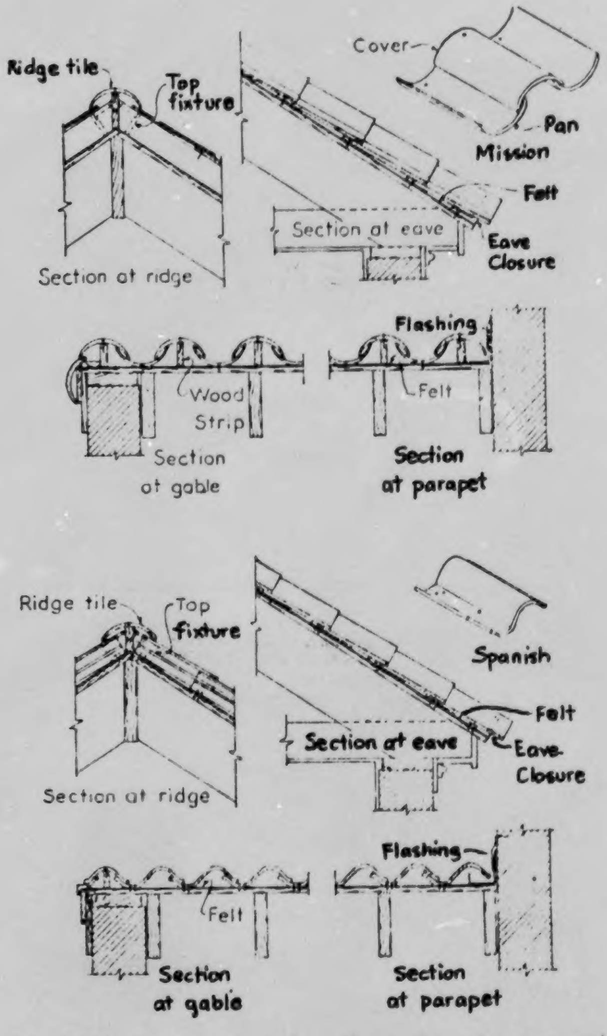

Ridge tile
Top fixture
Section at ridge
Cover
Pan
Mission
Felt
Section at eave
Eave Closure
Flashing
Wood Strip
Felt
Section at gable
Section at parapet
Ridge tile
Top fixture
Section at ridge
Spanish
Felt
Section at eave
Eave Closure
Flashing
Felt
Section at gable
Section at parapet

Fig. 10-52. Typical tile roofs. Above. Two piece pan and cover, commonly known as Mission tile. Below. Spanish tile.

Clay tile may be used over an old roof provided the old covering is in reasonably good condition, and the roof framing is heavy enough to stand the additional weight. Additional roof framing or bracing, if required, should be added before starting with the application of the tile.

Open type valleys are usually used. The edges of the metal should be turned back 1/2 in. forming a hem or water seal. The valley metal should be attached to the deck with cleats at the hem. Shingle nails should not be driven through metal valley linings.

Reroofing Over Old Shingles

Nail down all old shingles which are badly curled or warped. The use of under layment material generally is not required under asbestos shingles when they are laid over old wood or asphalt shingles. However, missing or badly decayed wood shingles should be replaced and the surfact brought to an even plane. If the top edges or corners of the new shingles do not rest on the butts of the old shingles, tilting will result. Wood strips, beveled, and equal in their greatest thickness to the butts of the old wood shingles, are satisfactory to use for leveling an old roof deck, figure 10-51.

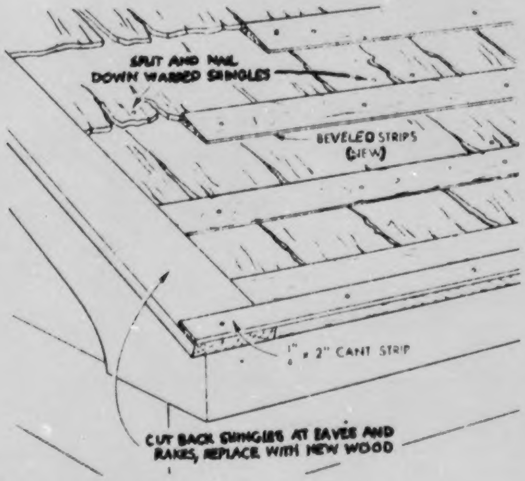

SPLIT AND NAIL DOWN WARPED SHINGLES
BEVELED STRIPS (NEW)
1/4" x 2" CANT STRIP
CUT BACK SHINGLES AT EAVES AND RAKES, REPLACE WITH NEW WOOD

Fig. 10-51. Preparation of old roof for reroofing with mineral fiber shingles.

Sometimes at the edge of the roof, the old wood shingles are found to be in bad condition and the sheathing is not in good shape. A substantial and more attractive job can be obtained by cutting away the old shingles and laying a new board 4 to 6 in. wide by 7/8 in. thick along the edges. This provides a solid base to which the new shingles will be nailed.

Build up old valleys with wood strips of a width and thickness adequate to bring them flush with the butts of the old wood shingles. Lay waterproof felt over hips, ridges, and at valleys.

Aluminum Roofing

Corrugated aluminum roofing, if properly applied, usually makes a long lasting roof. Seacoast exposure tests reported by the Bureau of Standards indicate this material is capable of resisting corrosion in such localities unless subjected to direct contact with salt-laden spray. Where this is likely to happen, aluminum roofing is not recommended.

Aluminum alloy sheets available for roofing usually have a corrugation spacing of 1 1/4 or 2 1/2 in. Recommendations for the installation of sheet metal regarding side lap and end lap are applicable to the laying of aluminum sheets. An important precaution to observe in laying aluminum roofing is to make sure that contact with other kinds of metal is avoided. Where this is not possible, both metals should be given a heavy coating of asphalt paint wherever the surfaces are in contact.

As aluminum is soft and the sheets used for roofing are relatively thin, they should be laid on tight sheathing or on decks with openings no more than 6 in. wide. Aluminum roofing should be nailed with not less than 90 nails to a square or about one nail for each square foot. It is recommended that aluminum alloy nails be used and that non-metallic washers be used between nail heads and the roofing.

If desired, the sheathing may be covered with water-resistant building paper or asphalt impregnated felt. Paper that absorbs and holds water should never be used. To avoid corrosion, aluminum sheets should be stored so that air will have free access to all sides; otherwise a white deposit will form causing them to deteriorate.

Terne Metal Roofing

Terne metal roofing is made of copper-bearing steel, heat-treated to provide the best balance between malleability and toughness. It is hot dipcoated with Terne metal, an alloy of 80 percent lead and 20 percent tin. The high weather resistance factor (notable in this type of roofing) is due primarily to the lead; tin is included because the resulting alloy makes a better bond with steel.

Grades are expressed in terms of the total weight of the coating on a given area. This area, by old trade custom, is the total area contained in a box of 112 sheets that are 20 in. x 28 in. in size, and amounts to 436 square feet. The best grade of Terne coating is 40 lb. and provides a roof surface that will last for many years.

A wide variety of sheet sizes are available, plus 50 foot seamless rolls in various widths. This permits its use for many different types of roofs and methods of application. It is used extensively for flashing around both roof and wall openings.

For best appearance and longest wear, Terne metal roofs must be painted. A linseed oil-based iron oxide primer is recommended for a base coat, over which nearly any exterior paint and color can be used.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

SOLDERING

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

SOLDERING

Many different types of metal are joined in manufacturing and installation of Solar systems. Manufacturers, with sophisticated and expensive machines, have the capability of using a variety of processes as required; however, the installer should become very proficient and skilled at using soldering techniques. These processes allow installers to achieve their objectives with reliability and professionalism.

Brazing and Soldering Defined

Brazing - A joining process using a filler metal with working temperature above 800°F, but below the melting point of the base metal.

Soldering - A joining process using a filler metal with working temperature below 800°F, and below the melting point of the base metal.

Heating Source

Brazing and soldering alloys can be applied with a portable, lightweight torch. Many repairs, in fact, can be performed with a small propane hand torch. (On occasion an oxy-acetylene torch may be better suited for in-shop work, but such equipment is not necessary for field repairs.)

Precleaning the Joint Area

Surface oxides must be removed for sound joining of metals. Cleaning is divided into two categories:

Mechanical - Joint areas should be abraded with materials such as plumber's sandpaper, emery cloth or steel wool. CAUTION: Always slant tubing downward when abrading so that shavings are not introduced into the system.

Chemical - In service trade applications, mechanical cleaning is usually adequate. If it is necessary to swab the interior surfaces of hard drawn tubing, a solvent such as "Freon-113" should be used. In refrigeration applications avoid using carbon tetrachloride or other chlorinated solvents.

Purpose of a Flux

1. To dissolve and sweep away surface films and oxides during the brazing or soldering process.
2. To prevent oxides from forming.
3. To "signal" moment when temperature is reached to apply the brazing alloy or solder.
4. To promote fluid flow and increase adhesion of the filler metal.

Fluxes are formulated for specific applications. Each flux is precisely calibrated with an activity range corresponding to the flow point of the filler metal.

In refrigeration applications, the service engineer needs a flux with sufficient activity, yet one that will not be drawn into the system.

Flux Residue Removal in Brazing and Soldering

In general, it is necessary to remove flux residues remaining after brazing and soldering applications because they may be corrosive and prevent finishing operations such as painting or chromium plating from being successfully completed. Flux residues may be removed by chemical or mechanical means, or by washing in hot water. NOTE: In refrigeration repairs, remove flux residue as soon as system is put under pressure, not before.

Washing in hot water: Flux residues remaining after applications with alloys of silver, zinc, zinc alloys and solders are usually removed by washing the joint area with hot water (104°F), followed by a careful rinse.

Mechanical cleaning: Mechanical cleaning by wire brushing, grinding, polishing, chipping, or sanding can be used to remove flux residues whenever it is impractical to remove them by washing. Examples are when the part is too large, too heavy or for some other reason the work cannot be cleaned by washing. However, mechanical cleaning generally causes some surface damage and should only be used where this will not affect the finished quality of the work.

Chemical cleaning: The following are some chemical solutions and techniques which are effective for removing flux residues. As chemical cleaning generally involves the use of acid solutions, extreme care must be taken to protect the skin, eyes, clothing, and equipment from damage when using these solutions.

Copper and Copper Alloys

To remove flux residues from copper and copper alloys such as brass, bronze, and other alloys in which copper is a major component, a solution of 10-15% sulphuric acid mixed with water, applied with a non-metallic brush is effective. This treatment will also restore the copper color to the work by removing oxides caused by brazing and soldering.

Ferrous Metals, Nickel Alloys, and Stainless Steels

To remove flux residues from ferrous metals, nickel and nickel alloys, a solution of 10-15% hydrochloric acid mixed with water, applied with a non-metallic brush is effective.

Aluminum and Aluminum Alloys

To remove flux residues from aluminum and aluminum alloys, immersion for one or two minutes in a 10-20% solution of caustic soda at between 122 and 176°F is effective. This treatment should be immediately followed by a hot water (120°F) rinse and application of a 20-30% solution of nitric acid mixed with water to neutralize the caustic soda residue. Finally, the work should be thoroughly rinsed again and immediately dried.

Filler Metals Most Commonly Employed

Silver Brazing Alloys (usually given the misnomer "silver solders").

Copper-Silver-Phosphorus Brazing Alloys.

Copper-Phosphorus Brazing Alloys.

Aluminum Brazing Alloys.

Soft Solders

The following tables list the All-State **products** for use by service engineers, including a description of each alloy, physical properties, and area of application.

ALL-STATE BRAZING & SOLDERING ALLOYS FOR THE SERVICE TRADES

CATEGORY OF FILLER METAL	ALL-STATE PRODUCT	DESCRIPTION	WORKING TEMP.	TENSILE STRENGTH	FLUX
SILVER BRAZING ALLOYS	No. 101	Contains 45% silver—Joins wide variety of metals with great strength. (Order in 1/16" x 18" rods; 8-oz., 1-lb. and 2-lb. coils; Silver Dispenser Units; special packaging called Siltube.	1125°F to 1145°F	To 52,000	No. 110 S-200 or S-300
	No. 101 FC *TRUCOTE	Same alloy, but with extruded coating. (Order in 4-oz. tubes, containing 1/16" x 18" rods.)			None
	No. 155	Cadmium Free silver brazing alloy used to braze objects from stainless steel food handling equipment to hot water systems. (Order in 1/16" x 18" rods; 8-oz., 1-lb. and 2-lb. coils.)	1150°F to 1200°F	To 50,000	No. 110 or S-200
	No. 155 FC *TRUCOTE	Same alloy, but with extruded coating. (Order 1/16" x 18" in 4-oz. plastic tubes.)			None
	No. 111 Coils Right-'N-Ready Pack	Contains 41% silver, plus toughening elements for ideal repair work—Lowest melting silver brazing alloy.	1110°F to 1150°F	To 50,000	No. 110 or S-200
	No. 155 Coils Right-'N-Ready Pack	Cadmium-free low temperature silver brazing alloy.	1150°F to 1200°F	To 50,000	No. 110 or S-200
COPPER-SILVER-PHOSPHORUS BRAZING ALLOYS	*SILFLO "5"	A 5% silver alloy for copper to copper joining where close fit-up cannot be maintained. (Order in .050" x 1/8" x 18", or .050" x 1/16" x 18" rods).	1300°F to 1500°F		None (†)
COPPER-SILVER-PHOSPHORUS BRAZING ALLOYS	*SILFLO "15"	A 15% silver alloy for copper to copper where joint ductility is vital. (Order in .050" x 1/8" x 18", or .050" x 1/16" x 18" rods).	1300°F to 1500°F		None (†)
COPPER-PHOSPHORUS BRAZING ALLOYS	*SILFLO "0"	Self fluxing alloy for copper to copper non-moving joints. (Order in 3/32" x 36", or 1/8" x 36" rods; or in *Phostubes, containing 4 oz. of rods in 18" lengths).	1350°F to 1550°F		None (†)
ALUMINUM BRAZING ALLOY	No. 31	For brazing light gauge aluminum sheet and tubing. (Order in 3/32" x 18", or 1/8" x 18" rods).	1075°F	To 30,000	No. 31
SOLDERS	No. 430	Unique, high strength solder for joining all metals except white metals; color matches stainless, and adheres to chrome plate. Cadmium Free. (Order in 1-lb. spools, 1/16" dia. and up, or in *Dynagrip Solder Kits, containing No. 430 Solder and *Duzall Flux).	430°F	To 15,000	*Duzall
	No. 430 Silver Bearing Paste Solder	Minutely pulverized silver-tin alloy suspended in an active flux to form a paste for application on all ferrous and non-ferrous metals (except white metals).	430°F	To 15,000	None
	*STRONGSET No. 509	For joining aluminum to aluminum or aluminum to dissimilar metals; "takes" to anodized aluminum without removing the anodizing. Yields unbelievable physical properties for a solder-range alloy. (Order in 1-lb. spools, 1/16" or 1/8" dia., or in *Strongset Solder Kits, containing No. 509 Solder and No. 509 Flux).	509°F	To 29,100	No. 509
	Paste Solder	Paint-on solder—Quick and easy to use—For plumbing applications, tubing, tinning, etc.—Water soluble. (Order in 1-lb. plastic jars).	375°F	To 6,500 Pressure	None

*Reg. U.S. Pat. Off.
†Use All-State No. S-200 Flux on copper to brass or bronze alloys.

SELECTION CHART FOR THE SERVICE TRADES

BASE METALS	ALUMINUM	COPPER	BRASS	STEEL	STAINLESS STEEL
ALUMINUM	31 56 Ribbon Strongset No. 509	509	509	509	509
COPPER	Strongset No. 509	101 or 101 FC 111, 155 or 155 FC *Silflo "0", "5", "15" 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC *Silflo "0", "5", "15" 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)
BRASS	Strongset No. 509	101 or 101 FC 111, 155 or 155 FC *Silflo "0", "5", "15" 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC *Silflo "0", "5", "15" 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)
STEEL	Strongset No. 509	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste) Paste Solder	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)
STAINLESS STEEL	Strongset No. 509	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)	101 or 101 FC 111, 155 or 155 FC 430 (Wire and Paste)

Legend: Brazing alloys (with working temperatures **above** 840°F (450°C)) appear in black ink.
Solders (with working temperatures **below** 840°F (450°C)) appear in red ink.

*Use A-S No. S-200 Flux.

The connections between the absorber plate and plumbing must withstand the thermal conditions. Traditional plumbing solders such as 50:50 tin: lead may have melting points that are too low; high-temperature solders or brazing (Table 8-5) are necessary in some systems to assure strength and durability. Rubber and plastic connections and plumbing are suitable in some low temperature systems.

Table 8-5. Working pressure as a function of temperature for soldered joints[a,b]

SOLDER OR BRAZING ALLOY	SERVICE TEMPERATURE (°F)	RATED INTERNAL WORKING PRESSURE (lb/in²)
50:50 Tin:lead	100 150 200 250	200 150 100 80
95:5 Tin:antimony	100 150 200 250	500 400 300 200
Brazing alloy (melting at or above 1000°F)	250 300	300 270

---

[a] Adapted from Anaconda American Brass Company. 1967. Pipe tube and fittings. Publication B-1, 26th edition. Anaconda American Brass Company, Waterbury, CT.

[b] For joints made of 1/4 to 1 inch copper tube and solder-type fittings.

Silver-Soldering

Silver-soldering, sometimes called "hard soldering", is a method of brazing at a low temperature that uses a wire or sheet of an alloy of silver and copper. Silver solder melts at about 1100°F, while brass spelter has a melting point of about 1700°F. It is difficult to braze brass with brass spelter; the work tends to melt almost as readily as the spelter rod, and can be completely destroyed in the process. To join parts made of brass, it is better to use silver solder, which is designed for brass, and which melts at a low enough temperature so that there is very little danger of the work being damaged.

A special flux in paste form is required for silver-soldering. It is essential that the parts be cleaned until bright and then covered with the flux before the oxides have a chance to form on the metal. Good capillary action is set up when this solder is applied and will cause the melted solder to be drawn into the joint. Leave a space between the parts of from .001 inch to .003 inch. Heat the work until a dark red color begins to be visible and the solder is melting and running like water. Then bring the heat up slowly. The solder will tend to melt before the meal is hot enough to make it stick; unless it is heated to the proper temperature, it will form balls, like drops of water on a hot stove, and run all over the work except into the joint. Both brass spelter and silver solder can be used to make very neat fillets after joints have been closed; melt a little over the joint and form it with the torch flame.

Silver solder can join either ferrous or nonferrous metals, but a special type is put out for use with brass or copper only, which is not suitable for iron or steel. This material is called Sil-phos and Phos-copper registered as "Silflo 0, Silflo 5 and Silflo 15". The numbers refer to the percentage of silver in the content. Aluminum cannot be brazed; aluminum parts can be soldered with an aluminum solder: the process is about as difficult as welding aluminum.

Flat sheets of silver solder are used to join two wide surfaces. A piece of this sheet solder is cut to fit between the surfaces, which have been cleaned and fluxed. The parts are then clamped together and heated until the solder melts. This heating must be done in a furnace so that the work will reach a uniform temperature over-all; do not attempt to use an acetylene torch for this type of work, as the heat from a torch will melt the solder only in spots, and the surrounding areas will remain too cold to receive the solder.

Silver solder in wire form is very useful: it can be fed into the joint by hand while the parts are heated with the torch. Soldering a joint like that between a nipple and a flange can be done easily with this form of solder. Form the wire solder into a ring that fits tightly between the parts being joined, then flux and heat them with the solder in place. Capillary action causes the solder to flow into the joint, and the excess forms a neat fillet. The residual flux can then be removed by washing the parts with hot water.

Soft Soldering

Soft or common solder is an alloy of tin, lead, and antimony with a melting point of from 300°F to 400°F. It is melted onto the tip of a large copper bar, called a soldering iron; then it flows from the tip of the iron onto the work.

Constant heating will oxidize this copper bar, causing a hard scale to form on its surface. If the scale is not removed promptly, it will eat into the copper and form deep pits to which solder will not adhere. To remove this scale, file it off while the soldering iron is hot, then rub the iron over a piece of ammonium chloride (sal ammoniac) to clean it. To keep the copper bar free of scale, it should be rubbed in melted solder, coating all four sides of the bar-a process called tinning.

Soft solder is obtainable in several degrees of hardness. The harder types require more heat for melting. For general-purpose soldering, a 50-50 solder (50 percent tin and 50 percent lead) is best. For heavy work, use bar solder heated with a large soldering iron. Wire solder, heated with an electric soldering iron or soldering gun, is better for smaller work. Wire solder is available either in the form of plain wire or as wire with a rosin core (for electrical work) or an acid core (for general-purpose work).

A small gas stove placed on top of the bench is very handy for heating heavy solid copper soldering irons. A portable blowtorch can be used to heat the iron for work done away from the bench. An electric soldering gun is by far the best tool to use for any work that is not so large that the heat will be conducted away faster than the gun can supply it: the metal to which the solder is to adhere must be kept hot enough so that the solder will not cool and harden before the joining has been completed.

The parts to be soldered must be perfectly clean and free of rust or grease. A flux is required for all soft soldering. Diluted hydrochloric acid makes a good cleaning agent for tin and galvanized iron. A flux called cut acid, made by dissolving metallic zinc in hydrochloric acid, is one of the best for these metals. Cut acid should not be used near joints such as electrical connections, which would be damaged by corrosion. For such jobs, a flux with a grease-and-rosin base is used. There are several noncorrosive fluxes on the market, and you should have a supply of one of these in your shop. Liquid fluxes for general-purpose soldering are also available; keep some on hand to save yourself the trouble of preparing your own cut acid. Since any flux containing hydrochloric acid will cause steel or iron to rust, keep it away from the tools on your bench. Store flux in bottles with rubber corks. If any should spill on the metal top of the bench, be sure to wash it off promptly or neutralize the acid with baking soda.

Sheet tin and galvanized iron are very easy to solder; steel and cast iron are more difficult to work with. Stainless steel can be soft soldered when a special flux is used.

The edges to be joined should be held rigidly in position and clamped together. Since the heat will warp the sheet metal, the two parts must be clamped tightly to maintain the proper width of the joint to be filled. Capillary action will cause the soft solder to run into and fill a tight joint, provided the metal is hot enough. You cannot make solder bridge across a wide gap. Shen joining two edges, it helps to tin them, that is, to cover the edges with a thin layer of solder before clamping them together. The molten solder will then combine with the tinned layer on each edge to fill the joint.

Joining two large surfaces is called sweating them. Clean the two surfaces, then tin them; the tinned layers should be thick enough to melt and form the joint when heat is applied. Clamp the surfaces together so that the pressure is distributed evenly over the entire surface area. Then heat the joint until the tinned layers unite. The clamps should not be removed until the work has cooled and the solder has set.

Some copper pipe fittings are intended to be soldered to a pipe; such a fitting is bored to fit properly on the pipe, and there is a small hole on the top of the fitting. Clean the inside of the fitting and the end of the pipe and cover them with flux, then insert the pipe into the fitting. While the joint is heated with a torch, feed wire solder into the small hole in the fitting; this will melt and fill the joint. The parts can be tinned before they are assembled, provided there is enough space for the pipe to be inserted after the tinning has cooled.

Soldering Techniques

Soldering Irons - Soldering is an easy way to join metals and wires if you know and use the correct procedures. The first step in soldering is to "tin" the soldering iron or gun. First clean the copper tip with steel wool until it is bright. Next, plug in the iron and wait until it gets hot, then melt some solder onto the tip. The tip will turn silver; this is called "tinning". An iron that has not been properly cleaned and tinned will produce a poorly soldered joint.

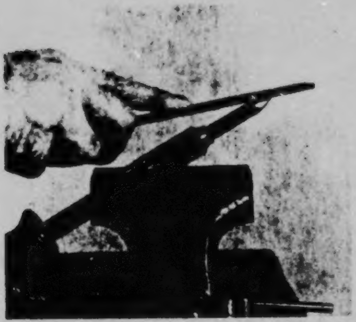
The work surfaces you are going to solder must also be cleaned. For this, use coarse steel wool, being sure not to touch the cleaned surface with your bare fingertips. The oil from your fingers can keep the solder from sticking.

Next, apply flux to the metal surfaces to be joined. The flux prevents oxidation on the metal surface, which would keep the metals from fusing. You can apply flux with your fingers or a brush.

A properly soldered joint can only be achieved when the iron is at its hottest. Apply the tip of the iron to the surface of the work to be soldered. It is important to understand that you apply the solder when the work surface, not the iron, is hot enough to melt the solder. When this temperature has been reached, the solder will flow around and over the cleaned and fluxed surfaces. If the solder does not adhere to the surfaces, the work has not been properly cleaned and fluxed.

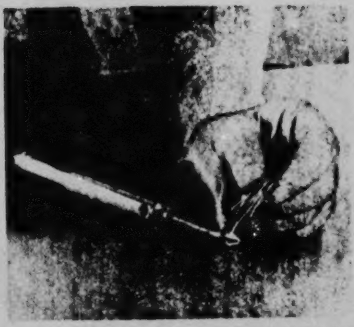
If you are soldering small joints, such as two wires together, or wires to electrical terminals, you can save time and effort by using rosin-core (flux-core) solder. This soldering wire has a core of rosin which acts as a flux during soldering.

Solder comes in both wire and bar form. You would most likely use the bar type when doing large soldering jobs such as sheet metal work.



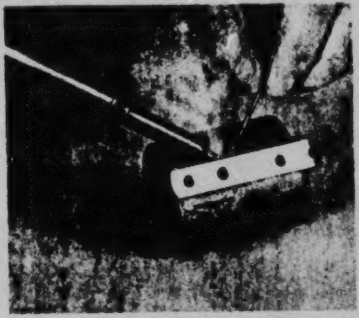
If the soldering iron is badly corroded and pitted, clamp it in a vise and clean the tip with a file. File all surfaces until bright copper is exposed. Finish cleaning with steel wool.

If the iron tip is dirty but not corroded, clean all sides with coarse steel wool. Avoid touching the cleaned tip with your fingers; this leaves an oil film which keeps solder from adhering.

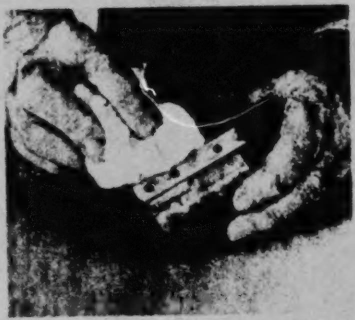


The iron must be at maximum heat for tinning. Plug it in and let it heat for at least 5 minutes. Then apply the flux-core solder so that it flows evenly over all sides of the tip.

Clean the surfaces of the pieces to be soldered with steel wool and apply paste flux to the cleaned areas. If you are using rosin core (flux-core) solder, there is no need to use flux.



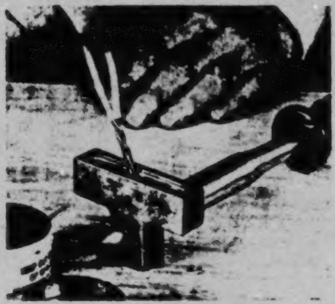
Apply the iron to the work until the work gets hot enough to melt the solder. Feed the solder along the work and slightly behind the iron. Use a large iron for heavy work.



Wipe off excess flux from the soldered joint with a clean rag. Do this while the soldered joint is still warm. Flux stains can be removed from a cold joint with paint thinner.

METAL	RECOMMENDED FLUX
Aluminum	Aluminum solder and special flux or flux combined with aluminum solder
Brass, bronze	Clean to bare metal and use rosin as flux
Cadmium plate	Rosin or flux used for galvanized iron
Copper	Clean to bare metal and use rosin as flux
Galvanized iron, iron	Chloride-type flux, commonly known as acid flux. Use liquid or paste form to suit work.
Lead	Water-soluble organic flux, such as Kester 415. Wash off flux after soldering.
Monel, nickel	Same as for galvanized iron
Pewter	Same as for lead. May vary with some alloys; check with manufacturer.
Silver	Use rosin-core solder
Stainless steel	Special stainless-steel flux
Steel	Same as for galvanized iron
Tin	Same as for galvanized iron
White metal	Same as for galvanized iron
Zinc	Same as for galvanized iron

Making a soldering pot



A soldering pot is handy when making many similar connections, such as joining wires. You can make one of a brass block, hacksawed as shown. Drill series of ¼ in. overlapping holes for well. Recess should fit snugly over tip of iron. Solder melts in about 4 minutes.

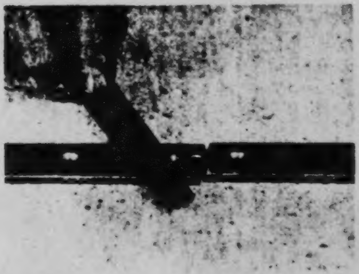
Hard soldering (used on steel, silver, gold, and bronze) makes a neater, stronger, and more permanent joint than soft soldering. A torch is needed to supply the high heat required for hard soldering. A propane torch is most convneient, but a Bunsen burner with a blowpipe can also be used.

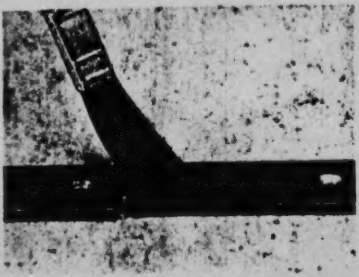
The first step in hard soldering is to clean the area where the pieces are to be joined. For this use a file, emery cloth, or wire brush. Clamp the pieces in position, apply flux to the joint, and then the recommended solder. Heat the metal until flux and solder melt. Insert thin sheets of solder into the joint. Keep the joint hot and continue to apply solder until all crevices are filled.

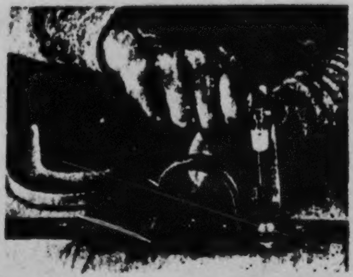
Use solder that is colored to match the metals being joined. For example, when joining sliver, use silver solder, an alloy of 8 parts silver, 3 parts copper and 1 part zinc; for gold, the proper solder is an alloy of silver, copper and gold.

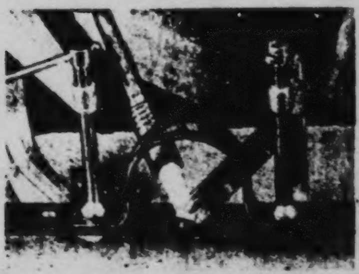
If you are doing a large job and do not have sufficient flux, a substitute can be made of powdered borax mixed with water to the consistancy of cream.

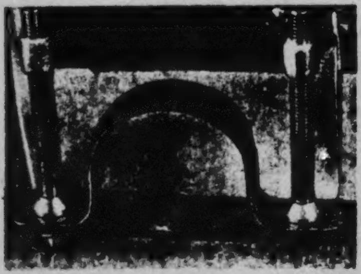
Melted flux leaves a brownish residue that can be removed from the soldered joint by submersion in a solution of 1 part sulphuric acid to 2 parts water. Let the work soak in this for about 30 minutes. Always add acid to water, never water to acid, when diluting sulphuric acid, and wear rubber gloves as well as protective goggles when you do it. Flux residue can sometimes be removed with boiling water alone if the joint is soaked before it cools.

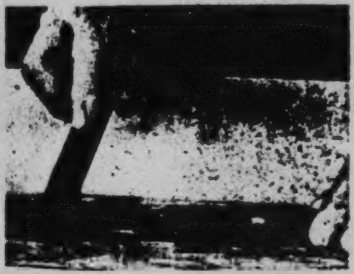

Sections to be joined by hard soldering must be cleaned with a file or emery cloth and placed on a fireproof surface such as firebrick or asbestos board.


A flux, such as borax and water paste, is then liberally applied to the cleaned surface with a small brush. Too much flux is better than too little.

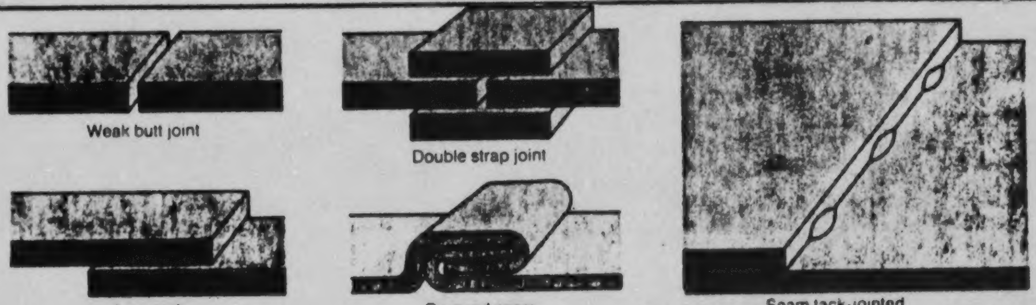

A bridge should be made from a piece of scrap metal bent in the middle to keep it away from the joint. A pair of clamps will also be needed.


The metal is heated to melt the hard solder as it is fed into the joint. Use the tip of the inner core of the flame, which is the hottest part.


The finished hard-soldered joint. Note that the clamps have been placed as far as possible from the joint in order to avoid heat loss at joint area.


After the solder has cooled, remove the flux by submerging the joint in a solution of 1 part sulphuric acid to 2 parts water, then file it smooth.

Soft soldering sheet metal



Weak butt joint

Double strap joint

Lap joint

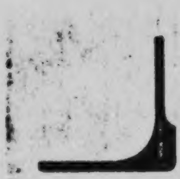
Grooved seam

Seam tack-jointed

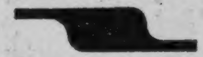
If a butt joint is unavoidable, it should be strengthened with metal sweat-soldered to both surfaces. A lap joint is better, a locked grooved seam stronger still. Large sheets should be tack-soldered before the joint is soldered.

Sweating

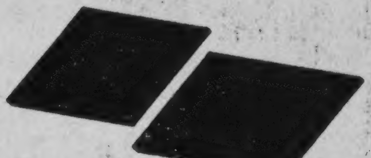
Sweating is a form of soldering in which the solder alone holds the pieces of metal together. The areas to be joined are cleaned and the surfaces made as smooth as possible so they can be brought into close contact. They are fluxed, coated with solder (tinned), assembled, clamped if possible, and heated until the solder remelts and unites. The joints must be held in position until the solder cools. Additional solder in the form of a fillet may be run along the joint edges for greater strength, waterproofing, and improved appearance.



A solder fillet adds to the strength of a right-angle joint.

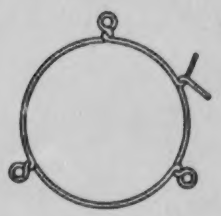


A fillet on an unlocked (folded) grooved seam.

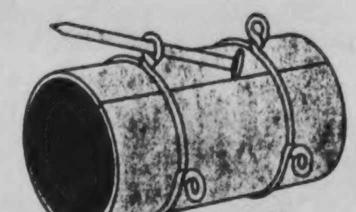


Tin both surfaces to be joined before sweating.

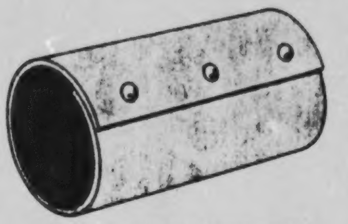
Solder united on a sweated joint.



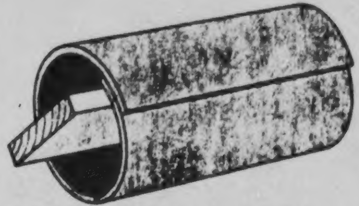
A wire tie is made from 18 gauge soft-iron binding wire. The loops are formed with a nail.



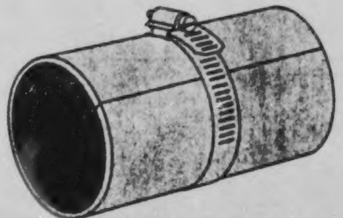
A butt-jointed cylinder is rigidly secured with wire. Strength is provided by hard soldering.



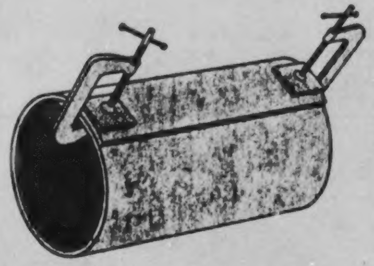
Permanent rivets or temporary screws may be used to hold the joint in place before soldering.



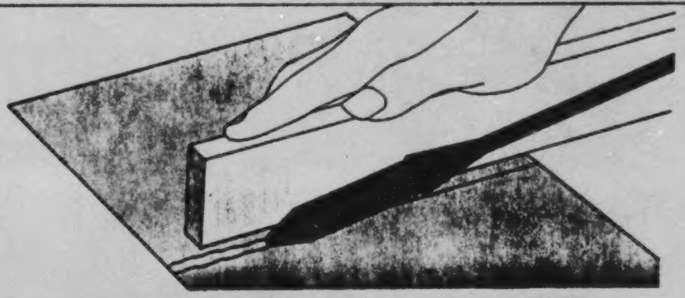
A fitted piece of hardboard will spring the joint in place and is easily removed later.



A pipe clamp or clamps are more easily adjusted and applied than soft-iron wire.



The jaws of two C-clamps are protected with scrap metal while being used to secure a joint.



Wood may be used to hold the joint together during the soldering process, as it is a poor conductor of heat.

Soft Soldering With A Torch

The purpose of the flux when soft soldering is to prevent oxidation of the material and flows out any impurities that may be present in the joint.

After the flux has been applied to the copper tubing, the torch flame should be moved up and down and around the tubing to give an even heat distribution.

The numbers 95-5, when speaking of soft solder, mean that there is 95% tin and 5% antimony in this solder. The melting range of 95-5 is 452° - 464°F. This is the temperature that the copper tubing will have to reach before the soft solder will begin to flow and adhere to the copper tubing.

As a general rule, the amount of soft solder (measured in length of wire solder) required to make a complete, well-tinned solder joint is 1/4 to 1/2 of the tubing diameter. An example of this is for a 1/2 inch diameter tubing, it would take from 1/8" to 1/4" of wire solder to make a complete soft solder joint.

Remember, you should always wear goggles or safety glasses when performing any soldering or silver brazing process. Also, keep in mind that if you use too much solder, that is, more than the 1/4 - 1/2 in the tubing diameter in length from the solder roll, the solder will flow down into the joint causing an obstruction within the piping. This obstruction may even be so severe as to create a stoppage or disturbance in the flow of the refrigerant gas which would increase the velocity at that point, and could cause serious problems in the refrigeration system.

One method of preventing solder from flowing into the joint and causing an obstruction is to use your fingers to rub lightly the last 1/8" of the piece of tubing to be joined. The oil from your fingers will prevent the solder from flowing beyond that point.

To solder:

1. The surfaces should be very clean.
2. The proper flux must be used.
3. The flux should be applied only to the male part of the joint, thereby preventing flux from entering the system.
4. The proper size tip should be selected insuring that it will provide enough heat to heat the joint to the appropriate temperature.
5. After the joint has reached the appropriate temperature, apply the solder evenly to the joint. Always apply the heat to the joint, never to the solder.
6. After the joint has cooled, be sure to clean the excess flux from the joint.

Silver Brazing

Silver brazing makes a much stronger joint than does the soft soldering. In silver brazing, a rod called "Sil-fos" is used. Sil-fos has a melting point of 1140 - 1150°F, but does not begin to flow until a temperature of 1300 - 1550°F is reached, depending upon the silver content of the rod being used.

When joining copper to copper, no flux is necessary when using Sil-fos.

When performing silver brazing on copper tubing, nitrogen should be flown through the tubing to prevent oxidation on the inside of the tubing. Try to avoid overheating the joint during the silver brazing process, as this would result in severe oxidation inside the tubing.

The procedures for silver brazing are essentially the same as for soft soldering except flux is not required when joining copper to copper. Development of skill using this material will come with practice.

Silver Soldering

The silver soldering process is somewhat different than silver brazing, in that the silver solder rod contains a greater amount of silver, providing a much stronger joint.

The flow point of the silver solder, however, is very nearly the same as the Sil-fos compound.

Silver soldering does require a flux. The flux used for the silver solder process is a white boraz flux. Here again the flux should be applied only to the male part of the joint.
Remember: You do not want to apply the torch flame directly to the soldering material. Always apply the torch flame to the joint.

The step-by-step procedure for silver soldering is as follows:

1. Clean the joints using sandcloth and brushes.

2. Fit the joints closely and support all parts.

3. Apply the appropriate flux for silver brazing alloy.

4. Heat evenly to the recommended temperature. Keep the torch tip moving constantly in a figure eight motion.

5. Apply the silver brazing alloy to the heated parts. Do not heat the silver solder with the torch.

6. Let the joint cool.

7. Clean the joint thoroughly, as this will remove the flux and keep any oxidation to the outside of the tubing from occurring.

Remember: Nitrogen should be blown through the tubing during the silver soldering process as this will prevent oxidation on the inside of the tubing.

A WORD OF CAUTION: Silver brazing materials sometimes contain cadmium. Fumes from heated cadmium are very poisonous. Be sure that the work space is well-ventilated. If at all possible, use silver brazing alloys which do not contain **cadmium**.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

PIPING PRACTICES

STUDENT MATERIAL

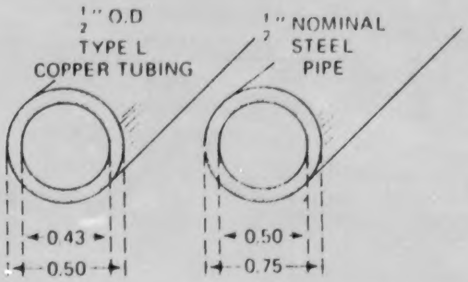
MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

PIPING PRACTICES

COPPER TUBING comes in what is known as hard drawn (rigid) and soft drawn (rolls). The hard drawn usually is available only in 20 foot lengths, and in type K, L, and M. The soft drawn copper comes in 50 ft. rolls of type L and M.

Type M soft drawn tubing is usually used for water piping because of the thin wall thickness which will not withstand the pressures found in high pressure refrigeration systems or water or steam systems. Types L or K are used for these applications. Type L copper tubing can be purchased in 50 ft. rolls or 20 ft. lengths.

Copper tubing is usually designated by its outside diameter, however, some plumbers still call for it by its nominal inside diameter.



Method of sizing tubing and pipe.

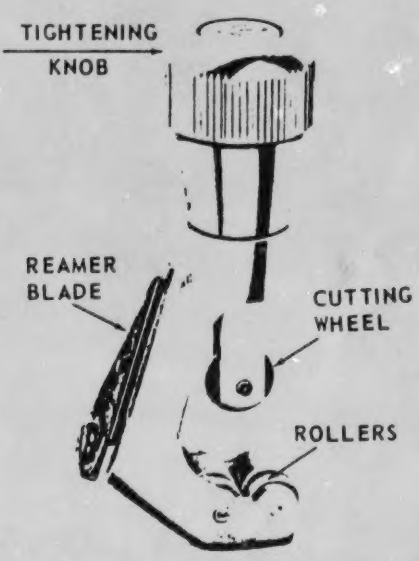
Copper tubing may also be purchased in type L of 3/16", 1/4" and 3/8" outside diameters of 10 and 20 ft. lengths. Type K may be purchased in 20 ft. lengths of 1/4" and 3/8" outside diameters. These sizes are available in addition to those shown in the table on the next page.

Note: The material presented herein will be limited to types K and L. However, keep in mind that type M is acceptable for use where pressure is not a factor, i.e. condensate drain lines, overflow lines, etc.

	DIAMETERS			
Type	*Outside Inches*	*Inside Inches*	*Wall Thickness Inches*	*Weight Per Foot Lbs.*
K	½	0.402	0.049	0.2691
	⅝	0.527	0.049	0.3437
	¾	0.652	0.049	0.4183
	⅞	0.745	0.065	0.6411
	1⅛	0.995	0.065	0.8390
	1⅜	1.245	0.065	1.037
	1⅝	1.481	0.072	1.362
	2⅛	1.959	0.083	2.064
	2⅝	2.435	0.095	2.927
	3⅛	2.907	0.109	4.003
	3⅝	3.385	0.120	5.122
L	½	0.430	0.035	0.1982
	⅝	0.545	0.040	0.2849
	¾	0.666	0.042	0.3621
	⅞	0.785	0.045	0.4518
	1⅛	1.025	0.050	0.6545
	1⅜	1.265	0.055	0.8840
	1⅝	1.505	0.060	1.143
	2⅛	1.985	0.070	1.752
	2⅝	2.465	0.080	2.479
	3⅛	2.945	0.090	3.326
	3⅝	3.425	0.100	4.292

Specifications of common copper tubing sizes.

Copper tubing may be cut to the correct **length** by using either a tubing cutter or a hacksaw. The tubing cutter is the preferred method in sizes of 2 1/8" O.D. or smaller.



Before the cutting process begins, it is desirable that the copper tubing be cleaned using a piece of sandcloth on the area in which the cut is to be made. This prevents having to clean the area for soft soldering, silver soldering or silver brazing after the cutting process is accomplished and, therefore, prevents the sandcloth grit and small copper filings from getting inside the copper tubing, which may happen if the cleaning process is done after the cut has been completed. Therefore, it is advisable to clean the area in which the cut is to be made before the cutting process is started.

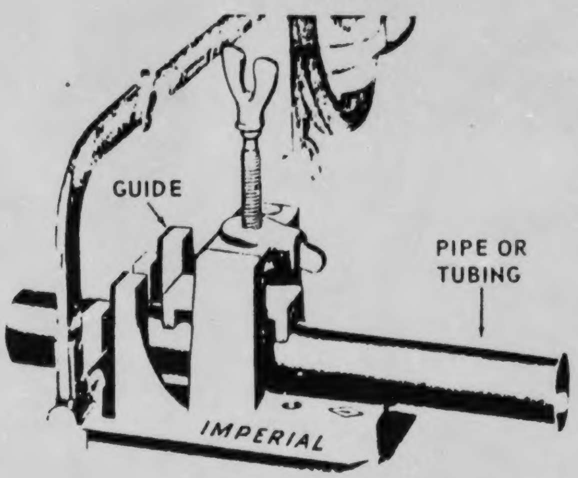
For a righthanded person, the tubing cutter should be rotated in a clockwise manner around the tubing. This will prevent the lead screw knob from working loose. For a lefthanded person, you would rotate the tubing cutter in a counterclockwise direction around the tubing. This also would prevent the lead screw from working loose. Too much pressure should not be applied to the lead screw, for this will collapse the tubing or cause large burrs inside the tubing. The normal amount of pressure put on the lead screw is usually 1/2 turn of the lead screw knob after rotating the tubing cutter around the tubing 2 to 5 turns. This will cause the cut to be square and leave very small burrs in the tubing.

The built-in reamer blade on back of the tubing cutter should always be put up so that the reamer blade does not endanger the hands as it is rotated around the copper tubing.

The cutting wheel and rollers on the tubing cutter should be kept in good condition. If the cutting wheel becomes nicked or chipped, it should be replaced with a new one.

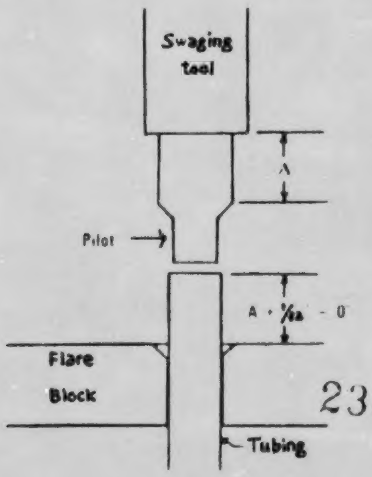
Copper tubing may also be cut with a hacksaw. The hacksaw blade should have no less than 14 teeth per inch. Cutting tubing with a hacksaw leaves small chips in the tubing which will contaminate the system. Be sure to remove them after the cut is complete.

The hacksaw cut must be kept square, so it is recommended that a sawing fixture be used.



Have the student prepare by sanding, cut and deburr 1/2" O.D. copper tubing in lengths of 2 inches and 3 inches, plus or minus 1/16". (Save these pieces for use in the next lab exercise).

Copper tubing is frequently joined by a process called swaging, (swedging) which expands one end of a piece of tubing to the correct size to receive the end of another piece of copper tubing. This process is very useful in making repairs of leaking areas in existing copper piping systems.



SET UP for SWAGING

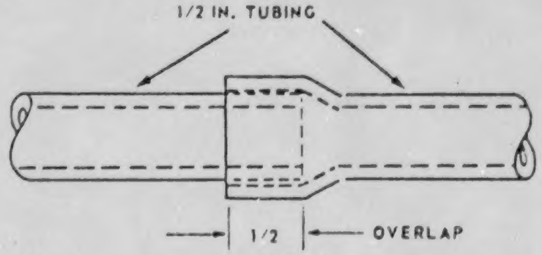
The swaging process is accomplished through the use of a **hammer**, a swaging tool, and a swaging or flaring block. The **copper tubing** should be placed in the flaring block with the correct amount of copper tubing sticking up above the flaring block.

While holding the swaging block in one hand, with the tubing clamped securely in the block, place the swaging tool pilot inside the copper tubing and begin the swaging process by taping the end of the swaging tool with a hammer. Tap the end of the swaging tool a couple of times with the hammer and then dislodge the swaging tool from the copper tubing. If you continue to tap the swaging tool until it is completely seated, it may become lodged in the tubing, and break the end of the swaging tool.

Remember: The swaged socket depth should equal the diameter of the tubing being swaged. For example, a 1/2: copper tubing being swaged should have a socket depth of 1/2".

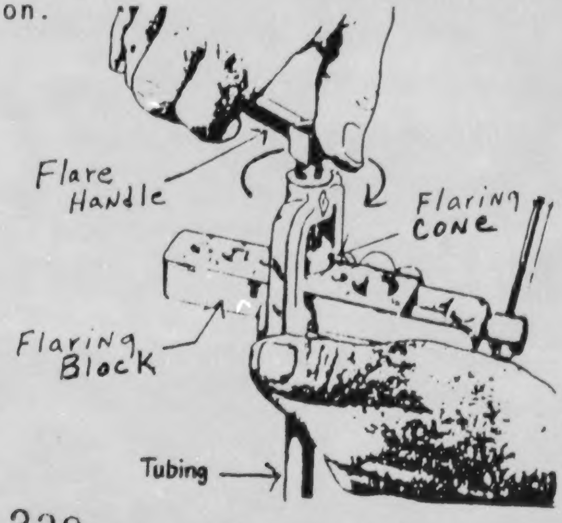
Remember: Always wear your safety glasses when using a hammer to strike any object.

Have the student swage one end of the 3" long, 1/2" O.D. copper tubing cut in the preceding lab exercise and swage to fit. Fitting of the two pieces should appear as shown below.



Oftentimes it is necessary to provide a means of disconnecting piping joints for access, maintenance procedures, additions of other piping or accessories. The best provision that allows this flexibility is the flare joint.

Caution: Be sure and install the flare nut before making the flare. Once the tubing is flared it is too late to put the flare nut on.



Flaring the Tubing

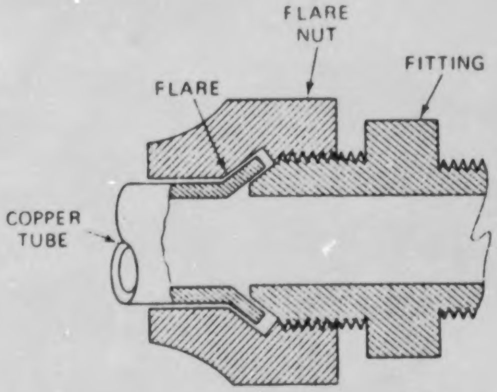
To make a flare of correct size using a flaring block, do the following:

1. Carefully prepare the end of the tubing for flaring. The end must be straight and square with the tube, and the burrs from the cutting operation must be removed by reaming.

2. Place the flare nut on the tubing with the open end towards the open end of the tubing. Insert the tube in the flaring tool so that it extends the correct amount above the flaring block. If the tube extends above the block too much, the flare will be too large and the flare nut will not fit over it. If too little tubing is above the flare block, the flare will be too small and will probably leak. Bring the anvil in contact with the end of the tubing. Advance it 1/2 turn, and then back it off 1/4. Then advance it 3/4 turn and back it off 1/4 turn. Repeat the forward movement and the backing off until the flare is formed. If the backing off motion is not accomplished, the tubing may become hardened and split the flare.

Making good flares only comes through practice.

3. Double flaring is usually done only on steel tubing or large copper tubing. Therefore, we will not demonstrate this procedure. If you feel you need to know this process, ask your instructor for a demonstration.



Cross-section of 45 angle flared fitting.

Lab Exercise

1. Obtain a set of flaring tools, a 1/4" flare nut, a 3/8" flare nut, a 1/2" flare nut, a piece of 1/4" copper 3" long, a piece if 3/8" copper 3" long, a piece of 1/2" copper 3" long and a deburring tool.

2. Select the 1/4" copper and deburr at this time.

3. After deburring, place the copper tubing in the flaring block, making sure that the tubing protrudes the correct height above the flaring block. Now begin the flaring process, remembering to back off the handle after you have turned 3/4 of a turn.

4. Complete the flaring process. Once you have completed the flaring process, try the flare nut on the tubing for size and make sure that the flare fits the nut.

5. Have your instructor check your flare on the 1/4" tubing.

6. Once your instructor is satisfied with the flare you have made, proceed to make flares on the 3/8" and 1/2" copper tubing.

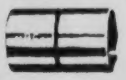
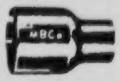
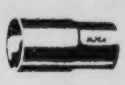
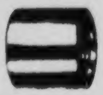
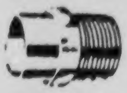
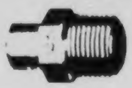
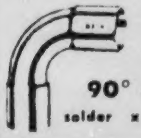
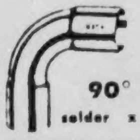
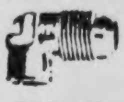
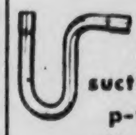
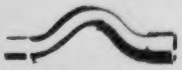
7. Have your instructor check your flares on the 3/8" and 1/4" tubing.

Copper fittings are used to join copper tubing lengths (couplings), make bends (turns) in the piping run (elbows), provide access parts, allow two or more pieces of tubing to join at common points (tees), join different diameters of tubing (reducers), and provide means of joining copper tubing to pipe threads, (male and female adapters) and many other special fittings.

The following two pages of copper fittings and their functions along with the chart showing available sizes, will assist the student in learning to identify these fittings by name and size.

Instructor: Select a rather comprehensive group of copper fittings and ask the student to identify them by name and size. Example: 7/8" O.D. slip fit to 3/4" male pipe thread.

WROT COPPER FITTINGS

style No. WC-400  **couplings—rolled stop** solder x solder	style No. WC-400S **couplings—staked stop** solder x solder	style No. WC-400NS **couplings—without stop** solder x solder	style No. WC-400R  **couplings—reducing** solder x solder	style No. WC-400E **eccentric couplings** solder x solder
style No. WC-407 **unions** solder x solder	style No. WC-403  **ftg reducers** fitting x solder	style No. WC-106 **flush bushings** fitting x solder	style No. WC-417  **flush bushings** fitting x f.p.t.	style No. WC-401  **adapters** solder x m.p.t.
style No. WC-402 **adapters** solder x f.p.t.	style No. WC-404  **ftg adapters** fitting x m.p.t.	style No. WC-405 **ftg adapters** fitting x f.p.t.	style No. WC-413 **adapters** solder x flare	style No. WC-414 **adapters** solder x f.flare
style No. WE-500— short radius  **90° ells** solder x solder	style No. WE-500L— long radius  **90° ells** solder x solder	style No. WE-503— short radius **90° ftg ells** fitting x solder	style No. WE-503L— long radius **90° ftg ells** fitting x solder	style No. WE-506— short radius **90° ftg ells** fitting x solder
style No. WE-506-L— long radius **90° ftg ells** fitting x fitting	style No. WE-504 **45° ells** solder x solder	style No. WE-505 **45° ftg ells** fitting x solder	style No. WE-507 **45° ftg ells** fitting x fitting	style No. WE-501 **90° ells** solder x m.p.t.
style No. WE-502 **90° ells** solder x f.p.t.	style No. WE-513  **90° ells** solder x flare	style No. WT-600 **tees** solder x solder x solder	style No. WT-602 **tees** solder x solder x f.p.t.	style No. WT-603 **crosses** solder x solder x solder x solder
style No. WE-512 **return bends** solder x solder	style No. WE-554P  **suction line p-traps** solder x solder	style No. WC-412  crossovers	style No. WC-415 **caps**	style No. WC-416 **ftg plugs**

MUELLER WROT COPPER FITTINGS

WROT PRESSURE FITTINGS Abbreviations C · Copper M · Male Pipe Thread F · Female Pipe Thread FTG Fitting

	STYLE		1/4	3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8	2-1/8	2-5/8	3-1/8	3-5/8	4-1/8
		Actual O.D. Size	1/4	3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8	2-1/8	2-5/8	3-1/8	3-5/8	4-1/8
		Nominal (I.D.) Size	1/8	1/4	3/8	1/2	5/8	3/4	1	1-1/4	1-1/2	2	2 1/2	3	3-1/2	4
ADAPTERS	WC-401	C x M	.98	.98	.98	.42		.66	1.28	2.02	2.68	3.80	10.40	14.20		28.40
	WC-401R	C x M · Reducing		.98	.98	.68	1.26	.96	2.32	3.12	4.54	7.04	22.00			
	WC-402	C x F	1.00	1.00	.86	.64		1.04	2.08	3.10	3.24	6.40	15.70	22.50		
	WC-402R	C x F · Reducing		.86	.86	.60	1.64	1.04	2.34	2.84	4.90	9.00				
	WC-110	C x SJ				1.02										
	WC-404	FTG x M			1.70	2.04		2.50	5.10	6.50	8.40	13.20	8.20			
	WC-404R	FTG x M · Reducing			1.70	1.80		2.60	4.70							
	WC-405	FTG x F			1.34	1.50		2.22	3.60	3.96	5.40	8.90	33.00			
	WC-405R	FTG x F · Reducing			1.34	1.80		2.44	4.46							
BUSHINGS	WC-403	FTG x C · Extended	.36	.36	.36	.32	.80	.60	1.00	1.34	1.66	3.44	9.20	11.00	29.80	22.50
	WC-106	FTG x C · Flush		.46	.36	.36	1.00	.54	1.24	1.90	2.36	6.30	19.00			50.00
	WC-417	FTG x F · Flush				.40		1.38	2.42	3.40	4.30	9.20				
CAPS – PLUGS	WC-415	C · Caps	.16	.16	.18	.16	.72	.38	.80	1.50	2.20	3.30	7.70	11.60	28.60	25.60
	WC-416	FTG · Plugs	.56	.56	.56	.38	1.16	1.06	1.50	2.90	3.90	4.20				
CROSSES	WT-601	C x C x C x C	4.20	5.20	7.00	9.00										

Abbreviations: C · Copper M · Male Pipe Thread F · Female Pipe Thread FTG · Fitting Red · Reducing S.R. · Short Radius L.R. · Long Radius

	STYLE		1/4	3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8	2-1/8	2-5/8	3-1/8	3-5/8	4-1/8
		Actual O.D. Size	1/4	3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8	2-1/8	2-5/8	3-1/8	3-5/8	4-1/8
		Nominal (I.D.) Size	1/8	1/4	3/8	1/2	5/8	3/4	1	1-1/4	1-1/2	2	2-1/2	3	3-1/2	4
COUPLINGS	WC-400*	C x C · Rolled Stop	.14	.14	.14	.16	.46	.34	.66	.98	1.30	2.32	4.30	6.30	11.60	12.10
	WC-400R	C x C · Reducing	.28	.28	.28	.28	.90	.58	1.06	2.00	2.28	3.24	9.20	15.00	32.00	30.00
	WC-400S*	C x C · Staked Stop	.14	.14	.14	.16	.46	.34	.66	.98	1.30	2.32	4.30	6.30	11.60	12.10
	WC-400NS	C x C · No Stop	.16	.16	.16	.20	.52	.42	.72	1.02	1.50	3.34	5.40	7.50		16.00
	WC-400E	C x C · Eccentric						1.86	2.66	4.70	8.50	12.50				
	WC-412	C x C · Crossover				2.70		11.20								
ELBOWS	WE-500SRH	C x C 90° S.R. · Heating			.60	.24		.48	.94							
	WE-500*	C x C 90° S.R.	.60	.60	.60	.24	1.00	.48	.94	1.68	2.36	3.94	7.50	11.20	68.00	25.00
	WE-500R	C x C 90° S.R. · Reducing		.60	.60	.80	1.18	.96	2.16	1.96	5.50	7.20				
	WE-503	FTG x C 90° S.R.	1.00	1.00	.80	.410	1.52	.74	1.62	3.42	4.14	8.60	19.40	21.50	76.00	43.00
	WF-506	FTG x FTG 90° S.R.		1.20	1.20	.90		1.70	4.22	5.50	7.60	15.50	39.20	48.00	86.00	100.00
	WE-500L*	C x C 90° L.R.	.84	.84	.84	.82	1.16	1.44	2.60	4.70	7.30	15.00	27.60	44.50	80.00	70.00
	WE-500LR	C x C 90° L.R. Reducing								5.60	7.20	14.20	26.50			
	WE-503L	FTG x C 90° L.R.		1.04	1.08	.82	1.52	1.76	5.50	5.80	8.20	16.30	32.30	44.50	80.00	70.00
	WE-506L	FTG x FTG 90° L.R.								5.60	8.00	16.20				
	WE-501	C x M 90°	1.22	1.46	1.46	2.00		3.50	6.60	7.60	10.60	16.40				
	WE-501R	C x M 90° Reducing		1.46	1.46	2.00	3.80	3.80	8.20	8.80	11.30	19.50				
	WE-502	C x F 90°	1.22	1.46	1.46	1.88		3.30	6.70	7.70	13.80	21.00				
	WE-502R	C x F 90° Reducing		1.46	1.46	1.90	3.80	3.80	9.20	8.80	13.80	21.00				
	WE-504	C x C 45°	1.86	1.46	.68	.410	1.14	.72	1.16	1.98	2.62	3.86	10.50	14.20	60.00	28.40
	WE-505	FTG x C 45°		1.22	.82	.56	1.44	.90	2.38	3.64	3.92	8.70	19.50	22.00		
	WE-507	FTG x FTG 45°			1.20	.90		1.46	3.90							
TEES	WT-600*	C x C x C	76	76	78	38	1.86	.94	2.10	3.56	4.62	8.20	18.60	28.60	106.00	47.00
	WT-600R	C x C x C Red Outlet	76	76	82	96	2.02	.94	1.54	9.16	8.16	5.80	18.80	16.00		36.90
	WT-600RR	C x C x C Red on Run & BH		84	84	.98	2.16	86	1.72	2.32	3.34	6.20	14.60	16.60		38.80
	WT-602	C x C x F	2.70	2.70	3.80	4.60										
	WT-602R	C x C x F Reducing		2.70	3.80											
UNIONS	WC-407	C x C		3.00	3.00	1.40		2.14	3.22							
P-TRAPS – SUCTION LINE	WE-554P	C x C				5.50	7.20	7.40	10.40	14.50	20.20	45.50				
STRAPS	WS-1100	two-hole tube straps	.14	.14	.14	.12	.18	.14	.14	.20	.24	.30				
	WS-1101S	perforated copper				12.90					24.80					

AIR CHAMBERS	WA-515	FTG	1/2 ftg x 1" O.D. x 6" Length	1.52	1/2 ftg x 1" O.D. x 12" Length 2.24	3/4 ftg x 1 O.D. x 12" Length 2.66

			1" O.D.	1-1/4" O.D.	1-1/2" O.D.	5"	6"
SIZES OVER 4 INCH AND SPECIAL O.D. SIZES	WC-400	C x C Coupling	.98	4.20	4.50		
	WC-400S	C x C Coupling				34.00	54.00
	WE-500	C x C 90° S.R. Elbows	3.14				190.00
	WE-500L	C x C 90° L.R. Elbows		4.80	7.60		
	WT-600	C x C x C Tees				140.00	230.00

Reducing fittings take net price of largest opening. Read in nominal size. 1/8 OD, 3/16 OD, 5/16 OD priced same as 1/4 inch nominal.

Brass fittings are used to join copper, steel and PVC piping of many sizes and configurations. They are particularly useful where permanent connections are not desired or where ease of construction is a factor. However, they usually result in a greater friction loss and turbulence than does copper fittings.

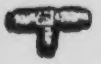
The following three pages contain pictures of the most common brass tubing and pipe fittings. Notice the name of the item and the various available sizes.

Instructor: Present the students with many different brass fittings of various sizes and ask them to identify them as to name and size.

Example: 1/4" flare x 1/4" flare x 1/8" M.P.T. Tee

MUELLER REFRIGERATION FLARED TUBE FITTINGS

FLARE TEE
FLARE X FLARE X FLARE



No.	O.D. Tube Inch	Each	
		1-99	100-499
T2-4	1/4	$1.12	$1.06
T2-5	5/16	1.28	1.22
T2-6	3/8	1.44	1.36
T2-8	1/2	2.02	1.92
T2-10	5/8	3.16	3.00
T2-12	3/4	6.04	5.74

FLARE TEE - REDUCING
FLARE X FLARE X FLARE

No.	Size In.	Each	
		1-99	100-499
TR2-46	1/4 x 1/4 x 3/8	$2.02	$1.92
TR2-64	3/8 x 3/8 x 1/4	2.02	1.92
TR2-68	3/8 x 3/8 x 1/2	2.60	2.48
TR2-84	1/2 x 1/2 x 1/4	2.60	2.48
TR2-86	1/2 x 1/2 x 3/8	2.60	2.48
TR2-810	1/2 x 1/2 x 5/8	3.72	3.54
TR2-106	5/8 x 5/8 x 3/8	3.72	3.54
TR2-108	5/8 x 5/8 x 1/2	3.72	3.54
TR2-1012	5/8 x 5/8 x 3/4	6.86	6.52
TR2-1210	3/4 x 3/4 x 5/8	6.86	6.52

TEE-M.P.T. ON SIDE
FLARE X FLARE X M.P.T.

No.	O.D. Tube Inch	Pipe Thread Inch	Each	
			1-99	100-499
T1-4A	1/4	1/8	$1.22	$1.16
T1-4B	1/4	1/4	1.78	1.70
T1-4C	1/4	3/8	2.38	2.26
T1-5B	5/16	1/4	1.70	1.62
T1-6B	3/8	1/4	1.78	1.70
T1-6C	3/8	3/8	2.38	2.26
T1-8B	1/2	1/4	2.74	2.60
T1-8C	1/2	3/8	2.38	2.26
T1-8D	1/2	1/2	3.28	3.10
T1-10C	5/8	3/8	3.28	3.10
T1-10D	5/8	1/2	3.08	2.92
T1-12D	3/4	1/2	6.88	6.54
T1-12E	3/4	1/2	6.88	6.54

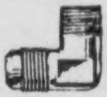
TEE-M.P.T. ON END
FLARE X M.P.T. X FLARE

No.	O.D. Tube Inch	Pipe Thread Inch	Each	
			1-99	100-499
T3-4A	1/4	1/8	$1.22	$1.16
T3-4B	1/4	1/4	1.75	1.70
T3-6B	3/8	1/4	1.78	1.70
T3-6C	3/8	3/8	2.38	2.26
T3-8C	1/2	3/8	2.38	2.26
T3-8D	1/2	1/2	3.28	3.12
T3-10D	5/8	~~1/2~~	3.28	3.12
T3-12E	3/4	3/4	6.88	6.54

FEMALE ELBOW
FLARE X F. FLARE

No.	Male to Female, in.	Each	
		1-99	100-499
E4-44	1/4 to 1/4	$1.50	$1.42
E4-66	3/8 to 3/8	2.32	2.22
E4-88	1/2 to 1/2	2.78	2.66
E4-1010	5/8 to 5/8	5.80	5.54
E4-1212	3/4 to 3/4	7.54	7.20

HALF UNION ELBOW
FLARE X M.P.T.



No.	Tube O.D., In.	Pipe Thread, In.	Each	
			1-99	100-499
E1-3A	3/16	1/8	$0.70	$0.66
E1-4A	1/4	1/8	.62	.58
E1-5A	5/16	1/8	.76	.72
E1-5B	5/16	1/4	1.34	1.28
E1-5C	5/16	3/8	.76	.72
E1-6A	3/8	1/8	1.08	1.02
E1-6B	3/8	1/4	1.34	1.28
E1-6C	3/8	3/8	1.08	1.02
E1-6E	3/8	3/4	1.34	1.28
E1-6D	3/8	1/2	.86	.82
E1-8B	1/2	1/4	2.22	2.10
E1-8C	1/2	3/8	2.66	2.52
E1-8D	1/2	1/2	1.56	1.48
E1-8E	1/2	3/4	1.34	1.28
E1-10C	5/8	3/8	2.22	2.10
E1-10D	5/8	1/2	4.12	3.92
E1-10E	5/8	3/4	4.12	2.92
E1-12D	3/4	1/2	4.32	4.10
E1-12E	3/4	3/4	4.32	4.10

FEMALE ELBOW
FLARE X F.P.T.

No.	Tube O.D., In.	Pipe Thread, In.	Each	
			1-99	100-499
E3-4A	1/4	1/8	$0.92	$0.88
E3-4B	1/4	1/4	1.22	1.16
E3-4C	1/4	3/8	2.26	2.14
E3-5A	5/16	1/8	1.08	1.02
E3-5B	5/16	1/4	1.40	1.34
E3-6A	3/8	1/8	1.40	1.34
E3-6B	3/8	1/4	1.22	1.16
E3-6C	3/8	3/8	1.94	1.84
E3-8C	1/2	3/8	1.94	1.84
E3-8D	1/2	1/2	4.34	4.12
E3-10D	5/8	1/2	4.84	4.60
E3-12D	3/4	1/2	4.84	4.60

UNION ELBOW
FLARE X FLARE

No	Tube O.D., In.	Each	
		1-99	100-499
E2-3	3/16	$0.98	$0.94
E2-4	1/4	.86	.82
E2-5	5/16	.98	.94
E2-6	3/8	1.22	1.16
E2-8	1/2	1.70	1.62
E2-10	5/8	2.42	2.30
E2-12	3/4	4.34	4.12

REDUCING UNION ELBOW
FLARE X FLARE

No.	Flare to Flare, in.	Each	
		1-99	100-499
ER2-64	3/8 x 1/4	$1.60	$1.52
ER2-84	1/2 x 1/4	2.08	1.98
ER2-86	1/2 x 3/8	2.08	1.98
ER2-108	5/8 x 1/2	2.80	2.66

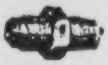
SWIVEL ELBOW
FLARE x F. FLARE

Catalog No.	Size, Inches		Each	
	Flare	F. Flare	1-99	100-499
ES4-44	1/4	1/4	$2.90	$2.76
ES4-66	3/8	3/8	3.52	3.34
ES4-68	3/8	1/2	4.10	3.90
ES4-88	1/2	1/2	4.10	3.90
ES4-1010	5/8	5/8	6.10	5.80

EXTRA HEAVY UNION
FLARE X FLARE

No.	Flare to Flare, In.	Each	
		1-99	100-199
UX2-4	1/4	$1.20	$1.14

EXTRA HEAVY HALF UNION
FLARE X M.P.T



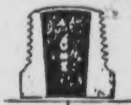
No.	Tube O.D., In.	Pipe Thread, In.	Each	
			1-99	100-199
UX1.4A	1/4	1/8	$1.04	$1.00
UX1.4B	1/4	1/4	1.04	1.00

FUSIBLE METAL FILLED HALF UNIONS

No.	Tube O.D., In.	Pipe Thread, In.	Each	
			1-99	100-199
FU-4B	1/4	1/4.	$1.76	$1.68
FU-4C	1/4	3/8	2.56	2.44
FU-6C	3/8	3/8	2.66	2.52

Note: Specify if for R-12 or R-22.
*MPT-275°-290° only.

FUSIBLE METAL FILLED PIPE PLUGS



No.	Pipe Thread, In.	Each	
		1-99	100-199
FP-A	1/8	$1.26	$1.20
FP-B	1/4	1.54	1.46
FP-C	3/8	1.98	1.88

Note: Specify if for R-12 or R-22.
MPT - 275° - 290° ONLY

MUELLER REFRIGERATION FLARED TUBE FITTINGS

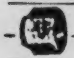
FLARE NUTS

LONG NUT

No.	Tube O.D., In.	Each 1-99	Each 100-499
N4-4	1/4	$0.50	$0.40
N4-5	5/16	.58	.56
N4-6	3/8	.62	.58
N4-8	1/2	.74	.70
N4-10	5/8	1.10	1.04
N4-12	3/4	1.90	1.80

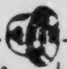
SHORT NUT

No.	Tube O.D., In.	Each 1-99	Each 100-499
NS4-3	3/16	$0.40	$0.38
NS4-4	1/4	.38	.36
NS4-5	5/16	.44	.42
NS4-6	3/8	.40	.38
NS4-8	1/2	.52	.50
NS4-10	5/8	.78	.74
NS4-12	3/4	1.38	1.32



SHORT REDUCING NUT

No.	Tube O.D., In.	Each 1-99	Each 100-499
NRS4-43	1/4 x 3/16	$0.52	$0.50
NRS4-54	5/16 x 1/4	.56	.54
NRS4-64	3/8 x 1/4	.52	.50
NRS4-65	3/8 x 5/16	.64	.60
NRS4-86	1/2 x 3/8	.64	.60
NRS4-108	5/8 x 1/2	.90	.86



FLARE SEAL BONNETS

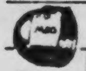
No.	Tube O.D., In.	Each 1-99	Each 100-499
B1-3	3/16	$0.10	$0.09
B1-4	1/4	.10	.09
B1-5	5/16	.16	.15
B1-6	3/8	.16	.15
B1-8	1/2	.22	.20
B1-10	5/8	.30	.28
B1-12	3/4	.23	.44

FLARE GASKET

No.	Tube O.D., In.	Each 1-99	Each 100-499
B2-3	3/16	$0.10	$0.09
B2-4	1/4	.10	.09
B2-5	5/16	.12	.11
B2-6	3/8	.14	.13
B2-8	1/2	.20	.19
B2-10	5/8	.24	.22
B2-12	3/4	.34	.32

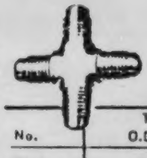
FLARE FITTING PLUGS

No.	Tube O.D., In.	Each 1-99	Each 100-499
P2-3	3/16	$0.36	$0.34
P2-4	1/4	.30	.28
P2-5	5/16	.46	.44
P2-6	3/8	.48	.46
P2-8	1/2	.74	.70
P2-10	5/8	1.22	1.16
P2-12	3/4	2.78	2.64



FLARE FITTING CAPS

No.	Tube O.D., In.	Each 1-99	Each 100-499
NS-3	3/16	$0.20	$0.19
NS-4	1/4	.18	.17
NS-5	5/16	.30	.28
~~NS-6~~	3/8	.28	.26
NS-8	1/2	.42	.40
NS-10	5/8	.58	.64
NS-12	3/4	1.56	1.49



FLARE CROSSES

No.	Tube O.D., In.	Each 1-99	Each 100-499
C1-4	1/4	$2.78	$2.64
C1-6	3/8	3.36	3.20
C1-8	1/2	4.34	4.12
C1-10	5/8	7.24	6.88

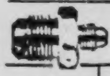
REFRIGERANT DRUM ADAPTERS

FEMALE STRAIGHT PIPE X FLARE

No.	Tube O.D., In.	Std. Fem. P.T., in.	Each 1-99	Each 100-499
K1-1	1/4	3/4	$2.58	$2.46
K1-3	3/8	3/4	3.86	3.66
K1-5	1/2	3/4	3.86	3.66
K1-8	1/4	1/2	2.58	2.46

DOUBLE END FLARE UNION

No.	Tube O.D., In.	Each 1-99	Each 100-499
U2-3	3/16	$0.48	$0.46
U2-4	1/4	.48	.46
U2-5	5/16	.64	.60
U2-6	3/8	.82	.78
U2-8	1/2	1.12	1.06
U2-10	5/8	1.58	1.30
U2-12	3/4	2.84	2.70



REDUCING COUPLINGS

FLARE X FLARE

No.	Tube O.D., In.	Each 1-99	Each 100-499
UR2-43	1/4 to 3/16	$1.00	$0.96
UR2-54	5/16 to 1/4	1.00	.96
UR2-64	3/8 to 1/4	1.22	1.16
UR2-65	3/8 to 5/16	1.22	1.16
UR2-84	1/2 to 1/4	1.50	1.42
UR2-86	1/2 to 3/8	1.50	1.42
UR2-106	5/8 to 3/8	2.22	2.10
UR2-108	5/8 to 1/2	2.22	2.10
UR2-128	3/4 to 1/2	3.52	3.34
UR2-1210	3/4 to 5/8	3.52	3.34

VALVE CONNECTOR

FEMALE FLARE X FEMALE FLARE

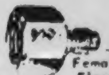
No.	Tube O.D., In.	Each 1-99	Each 100-499
U4-4	1/4	$1.00	$0.96
U4-6	3/8	1.50	1.42
U4-8	1/2	2.00	1.92
U4-10	5/8	3.00	2.86
U4-12	3/4	6.12	5.84

SWIVEL NUT VALVE CONNECTOR

FEMALE FLARE X FEMALE FLARE

No.	Tube O.D. In.	Each 1-99	Each 100-499
US4-4	1/4	$2.08	$1.98
US4-5	5/16	2.20	2.10
US4-6	3/8	2.38	2.26
US4-8	1/2	2.64	2.52
US4-10	5/8	3.52	3.66

FITTING REDUCERS



No.	Female Flare	Male Flare	Each 1-99	Each 100-499
UR3-34	3/16 to	1/4	$1.26	$1.20
UR3-43	1/4 to	3/16	1.26	1.20
UR3-45	1/4 to	5/16	1.26	1.20
UR3-46	1/4 to	3/8	1.26	1.20
UR3-48	1/4 to	1/2	1.48	1.40
UR3-54	5/16 to	1/4	1.48	1.40
UR3-56	5/16 to	3/8	1.48	1.40
UR3-64	3/8 to	1/4	1.72	1.64
UR3-68	3/8 to	1/2	1.72	1.64
UR3-84	1/2 to	1/4	1.72	1.64
UR3-86	1/2 to	3/8	2.18	2.08
UR3-810	1/2 to	5/8	2.18	2.08
UR3-812	1/2 to	3/4	3.00	2.86
UR3-108	5/8 to	1/2	3.00	2.86
UR3-1012	5/8 to	3/4	3.00	2.86
UR3-1210	3/4 to	5/8	5.32	5.06

HALF UNION COUPLING

FLARE X M.P.T.

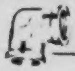
No.	Tube O.D., In.	Pipe Thread, in.	Each 1-99	Each 100-499
U1-3A	3/16	1/8	$0.38	$0.36
U1-4A	1/4	1/8	.38	.36
U1-4B	1/4	1/4	.56	.54
U1-4C	1/4	3/8	1.00	.96
U1-4D	1/4	1/2	1.12	1.06
U1-5A	5/16	1/8	.68	.64
U1-5B	5/16	1/4	.76	.74
U1-5C	5/16	3/8	.86	.82
U1-6A	3/8	1/8	.96	.92
U1-6B	3/8	1/4	.64	.60
U1-6C	3/8	3/8	.86	.82
U1-6D	3/8	1/2	1.28	1.22
U1-6E	3/8	3/4	2.92	$2.78
U1-8A	1/2	1/8	1.24	1.18
U1-8B	1/2	1/4	1.24	1.18
U1-8C	1/2	3/8	.86	.82
U1-8D	1/2	1/2	1.12	1.06
U1-8E	1/2	3/4	2.92	2.78
U1-10B	5/8	1/4	1.96	1.86
U1-10C	5/8	3/8	1.96	1.86
U1-10D	5/8	1/2	1.72	1.64
U1-10E	5/8	3/4	2.92	2.78
U1-12C	3/4	3/8	2.42	2.32
U1-12D	3/4	1/2	2.92	2.78
U1-12E	3/4	3/4	2.92	2.78

FEMALE COUPLING

FLARE X F.P.T.

No.	Tube O.D., In.	Pipe Thread, In.	Each 1-99	Each 100-499
U3-3A	3/16	1/8	$0.56	$0.54
U3-4A	1/4	1/8	.56	.54
U3-4B	1/4	1/4	.80	.76
U3-4C	1/4	3/8	1.50	1.42
U3-5A	5/16	1/8	.72	.68
U3-5B	5/16	1/4	–	–
U3-6A	3/8	1/8	1.16	1.12
U3-6B	3/8	1/4	.96	.90
U3-6C	3/8	3/8	1.50	1.42
U3-6D	3/8	1/2	2.42	2.32
U3-8B	1/2	1/4	1.50	1.42
U3-8C	1/2	3/8	1.30	1.24
U3-8D	1/2	1/2	2.42	2.32
U3-10C	5/8	3/8	2.42	2.32
U3-10D	5/8	1/2	2.42	2.32
U3-10E	5/8	3/4	5.56	5.32
U3-12D	3/4	1/2	5.56	5.32
U3-12E	3/4	3/4	5.56	5.32

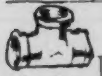
IMPERIAL BRASS PIPE FITTINGS



NO. 100-B ELBOW

Female P.T. to Female P.T.

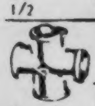
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.46	$0.38
1/4	25	.78	.64
3/8	25	1.86	1.54
1/2	5	2.18	2.62



NO. 101-B TEE

Female P.T. to Female to Female P.T.

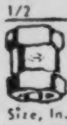
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.68	$0.56
1/4	25	1.08	.88
3/8	25	2.44	2.02
1/2	5	3.82	3.16



NO. 102-B CROSS

Female P.T.

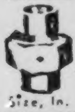
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	5	$1.24	$1.02
1/4	5	1.78	1.48
3/8	5	3.78	3.14
1/2	5	7.48	6.18



NO. 103-B COUPLING

Female P.T. to Female P.T.

Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.36	$0.30
1/4	25	.52	.42
3/8	25	1.08	.88
1/2	5	1.90	1.56



NO. 104-B UNION

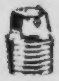
Female P.T. to Female P.T.

Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	5	$2.84	$2.34
1/4	5	4.08	3.38
3/8	5	5.08	4.20
1/2	5	5.32	4.40

NO. 108-B CAP

Female P.T.

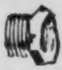
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	10	$0.26	$0.22
1/4	10	.60	.48
3/8	5	1.06	.88
1/2	5	1.56	1.30



NO. 109-B PLUG

Male P.T.

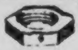
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.18	$0.14
1/4	25	.26	.22
3/8	25	.44	.36
1/2	5	.64	.54



NO. 110-B BUSHING

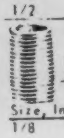
Male P.T. to Female P.T.

Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/4 x 1/8	25	$0.30	$0.24
3/8 x 1/8	25	.46	.38
3/8 x 1/4	25	.42	.34
1/2 x 1/8	10	.78	.64
1/2 x 1/4	10	.72	.60
1/2 x 3/8	10	.74	.60
3/4 x 3/8	5	1.80	1.50
3/4 x 1/2	5	1.72	1.42



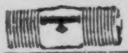
NO. 111-B LOCK NUT

Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	10	$0.24	$0.20
1/4	10	.24	.20
3/8	5	.48	..40
1/2	5	.98	.82



NO. 112-B CLOSE NIPPLE

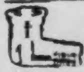
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.18	$0.16
1/4	25	.26	.22
3/8	25	.76	.62
1/2	5	1.22	1.02



NO. 113-B LONG NIPPLE

Male P.T.

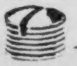
Size, In.	Lgth., In.	Std. Pkg. Qty.	Price Each	
			1-99	100-199
1/8	1-1/2	25	$0.54	$0.44
1/4	1-1/2	25	.80	.66
3/8	1-1/2	25	.96	.80
1/2	1-1/2	5	1.34	1.10
1/8	2	25	.66	.56
1/4	2	25	.94	.78
3/8	2	25	1.20	.98
1/2	2	[illegible]	1.66	1.36
1/8	2-1/2	25	.84	.70
1/4	2-1/2	25	1.08	.90
3/8	2-1/2	25	1.26	1.04
1/2	2-1/2	2	1.98	1.62
1/8	3	5	.94	.78
1/4	3	5	1.16	.96
3/8	3	2	1.58	1.30
1/2	3	2	2.36	1.94
1/8	3-1/2	5	.96	.80
1/4	3-1/2	5	1.48	1.72
3/8	3-1/2	2	1.88	1.56
1/2	3-1/2	2	2.50	2.08



NO. 116-B STREET ELBOW

Female P.T. to Male P.T.

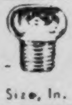
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.46	$0.38
1/4	25	.74	.62
3/8	25	1.44	1.18
1/2	5	3.32	2.76



NO. 117-B PLUG

Male P.T.

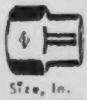
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	20	$0.14	$0.12
1/4	10	.24	.20
3/8	5	.58	.48



NO. 118-B WING PLUG

Male P.T.

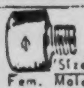
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	10	$0.50	$0.42
1/4	5	.58	.48
3/8	5	1.30	1.08
1/2	5	1.74	1.44



NO. 119-3 REDUCING BUSHING

Female P.T. to Female P.T.

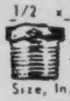
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/4 x 1/8	25	$0.68	$0.56
3/8 x 1/4	25	1.10	.90
1/2 x 3/8	5	1.56	1.28



NO. 120-B ADAPTER

Female P.T. to Male P.T.

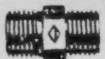
Size Fem. Thrd. x Male Thrd. Inches	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8 x 1/8	25	$0.38	$0.30
1/4 x 1/8	25	.50	.40
1/4 x 1/4	25	.92	.76
3/8 x 1/4	25	.96	.80
1/2 x 3/8	5	1.58	1.32



NO. 121-B PLUG

Male P.T.

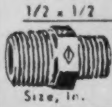
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.18	$0.16
1/4	25	.32	.26
3/8	25	.60	.48
1/2	5	.96	.80
3/4	5	2.40	1.98



NO. 122-B HEX NIPPLE

Male P.T. to Male P.T.

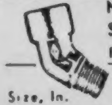
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8 x 1/8	25	$0.26	$0.22
1/4 x 1/4	25	.46	.38
3/8 x 3/8	25	.78	.64
1/2 x 1/2	5	1.42	1.16



NO. 123-B REDUCING NIPPLE

Male P.T. to Male P.T.

Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/4 x 1/8	10	$0.52	$0.42
3/8 x 1/4	5	.78	.64

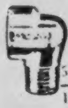


NO. 124-B 45 DEGREE STREET ELBOW

Female P.T. to Male P.T.

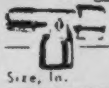
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8	25	$0.64	$0.54
1/4	25	.86	.72
3/8	5	2.16	[illegible].80
1/2	5	3.16	2.62

NO. 126-B OILFILTER ELBOW



Female P.T to Male P.T.

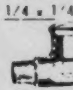
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8 x 1/8	5	$1.94	$0.94



NO. 127-B TEE

Male P.T. to Female P.T. to Female P.T.

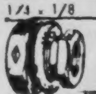
Size, In.	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/8 x 1/8 x 1/8	10	$0.86	$0.72
1/4 x 1/4 x 1/4	5	1.72	1.42



NO. 128-B REDUCING STREET ELBOW

Female P.T. to Male P.T.

Size, In. Fem. Male	Std. Pkg. Qty.	Price Each	
		1-99	100-199
1/4 x 1/8	5	$1.10	$0.92



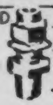
NO. 129-B BULKHEAD ADAPTER

Female P.T. to Female P.T.

Size, In.	Lgth., In.	Price Each	
		1-99	100-199
1/8	1-1/2	$2.86	$2.00
1/4	15/16	2.74	1.9[illegible]
1/4	1-1/2	2.86	2.00
3/8	1-5/16	6.08	4.26
1/2	1-1/2	6.26	4.38

NO. 130-B BULKHEAD ADAPTER

Male P.T. to Male P.T. to Female P.T.

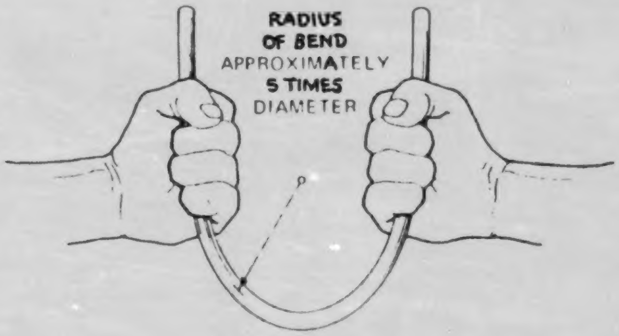


Size, Ins			Price Each	
Male	Fem	Lgth	1-99	100-199
½	⅛	2 5/32	$6.38	$4.46
½	⅛	2 11/32	6.72	4.70

Where possible, copper tubing should be bent for making turns, traps or crossovers. Bends reduce turbulence and friction loss considerably, resulting in less head requirements and sometimes allows the use of smaller tubing for the required piping task.

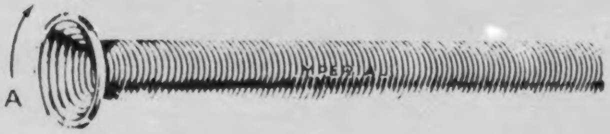
There are three methods of bending copper tubing. They are: 1. bending by hand, 2. spring benders, and 3. mechanical benders.

Bends made by hand should have a radius no less than 5 times the tubing diameter. Hand bending works quite well with tubing no larger than 3/8" diameter. Larger diameters should be bent by the spring bender or mechanical bender. Use the hand bending method on soft copper only.



Recommended technique in bending tubing by hand.

Spring benders are preferred over hand bending specifically for 1/2" O.D., 5/8" O.D. and 3/4" O.D. tubing. The spring bender may be used on the outside or inside of the tubing. Inside use is not recommended, but with practice it can be done. Spring benders come in assorted sizes through 7/8" O.D., but bending 7/8" O.D. tubing with the spring bender is very difficult. Use the spring bender for bending soft copper only.

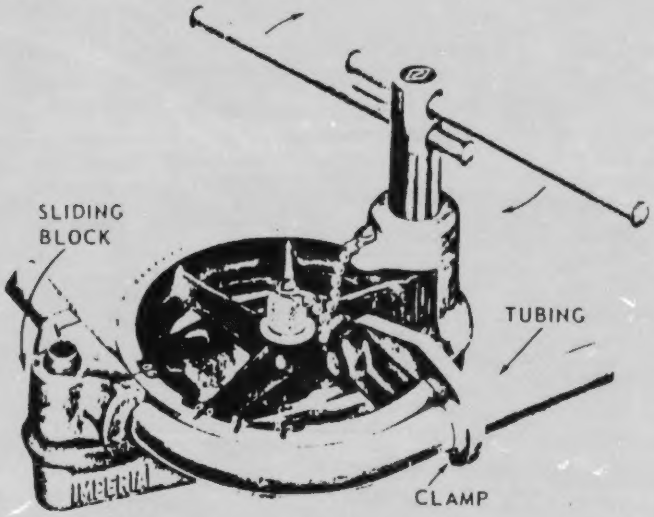


Tube bending spring may be fitted either outside or inside copper tube while bending tube. Bending spring reduces danger of flattening tube while it is being bent. A—Twist to remove spring.

The mechanical bender makes a very **precise, short radius** bend and is the preferred method for bending copper tubing.

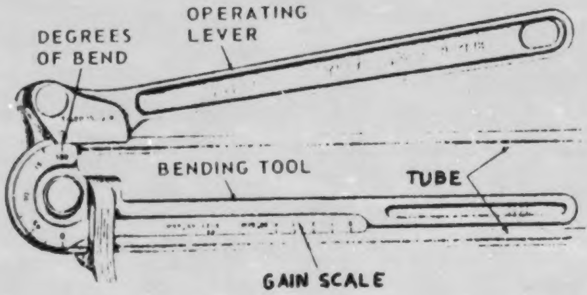
The bender comes in several forms, but the most popular ones are the lever type bender and the gear type bender. These benders can make bends accurage to ± 1/32 of an inch.

Gear type bender


SLIDING BLOCK
TUBING
IMPERIAL
CLAMP

Tube bender which will produce accurate bends and will reduce danger of flattening or buckling tube while it is being bent.

Lever type bender


DEGREES OF BEND
OPERATING LEVER
BENDING TOOL
TUBE
GAIN SCALE

Lever type tube bending tool. As shown, tool is making 180 deg. bend. Tubing is stretched slightly in length during bend. Amount of the stretch (gain) is indicated on the bending tool.

Occasionally copper tubing must be bent before it is attached to the components and many times this requires several bends in different directions. There is a method whereby the required length including bend allowance can be calculated, the length cut, the bends made and then the bent component placed in position for assembly.

The procedures for accomplishing this task are as follows:

The bending tool is useful in making bends that require close tolerances and is a must in bending steel or brass tubing.

In order that quality bends may be made, follow these procedures:

1. Oil the tubing in the bend area.

2. Place the tubing in the bending tool making sure the clamp is in position over the tubing.

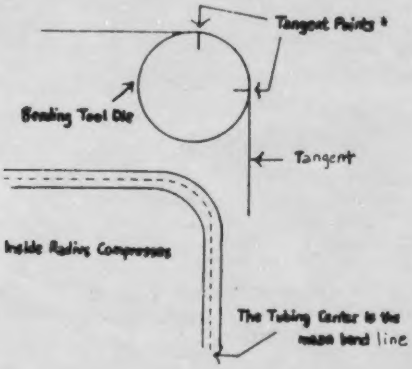
3. While holding the bending tool stationary, proceed to move the operating lever around the bending tool die which forms the bend of the tubing.

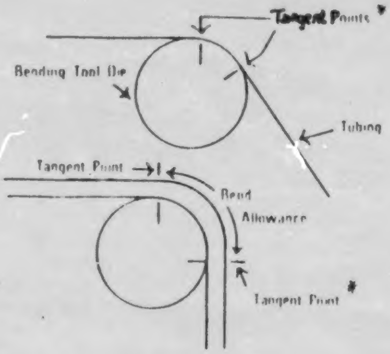
4. When the "O" on the operating lever is in alignment with the desired degree of bend on the bending tool, stop the bend and remove the tubing from the bender.

5. Bends of less than the desired degree of bend may be corrected by placing the tubing in the tool again and "bending it a little more". Bends of more than the desired degree of bend should be "straightened" the required amount using the hands where possible.

Making bends of close tolerance with the bending tool may be accomplished by following these procedures.

6. Study the diagrams below to be familiar with the terminology.


Tangent Points *
Bending Tool Die
Tangent
Inside Radius Compresses
The Tubing Center is the mean bend line


Tangent Points *
Bending Tool Die
Tubing
Tangent Point
Bend Allowance
Tangent Point *

* Tangent Point - the point where a straight line would intersect (touch) the arc of a circle.

7. Making bends where the tubing must **be cut to length** before the bend is made requires the following steps.

   A. Add the straight line lengths from **the ends** of the tubing to the tangent points of the bend. (Include straight lengths between the tangent points if more than one bend is required.)

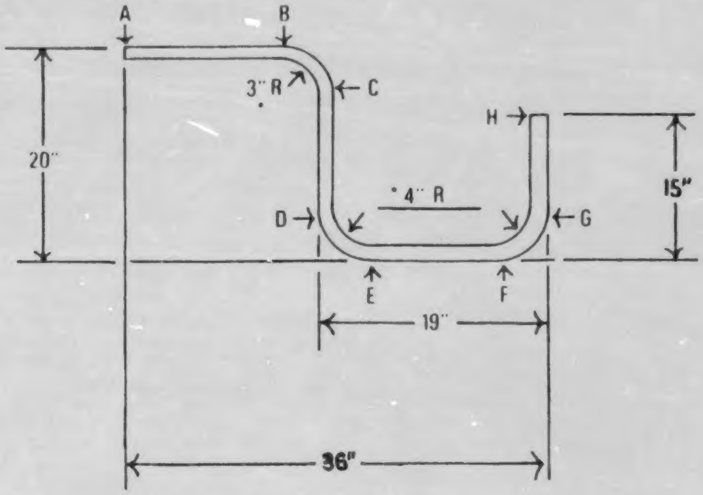
   B. Calculate the amount of material required for the bend allowance(s) using this formula:

$$** \text{ Bend allowance} = \frac{\text{angle of bend}}{360} \quad \text{Inside Radius of Bend} + \frac{\text{Dia}}{2} \quad 2\pi$$

   C. Sum of A + Sum of B = required tubing length.

8. Example problem with procedures:

   1/2" O.D. soft copper tubing. All **bends** 90^{0}



Straight Lengths
obtain demensions at the inside radius

A to B = 36 - 19 - 3 = (14")
C to D = 20 - 1/2 - 3 -4 -1/2 = (12"0
E to F = 19 - 1/2 - 4 -4 -1/2 = (10")
G to H = 15 - 1/2 - 4 = (10 1/2")

Total 46 1/2"

** A better formula for calculating bend allowance is:

B.A. = Mean Radius x .01745 x angle of bend

Bend Allowances
B to C = 90/360 (3 + .25) 2π = 5.105
D to E = 90/360 (4 + .25) 2π = 6.675
F to G = 90/360 (4 + .25) 2π = 6.675

Total 18.455" (18.7/16")

Blank length need for the problem;

46 1/2" + 18 7/16" = 64 15/16"

* Procedure for bending example problem.

1. Mark the tangent point at B on the tubing, place the tubing in the 1/2" bending tool with a 3" radius, matching the "0" on the bending tool with the tangent point marked on the tubing.

2. Clamp the tubing in the tool holding the tubing in place and bend the tubing 90°.

3. Mark the tubing at tangent point at E, place tubing in the bending tool matching the "0" with the tangent point.

4. Clamp the tubing in the tool holding the tubing in place and the previous bend parallel to the tool. Bend the tubing 90°.

5. Mark the tubing at tangent point G, place the tubing in the bending tool matching the "0" with the tangent point.

6. Clamp the tubing in the tool, holding it in place and the previous bends parallel to the bending tool. Bend the tubing 90°.

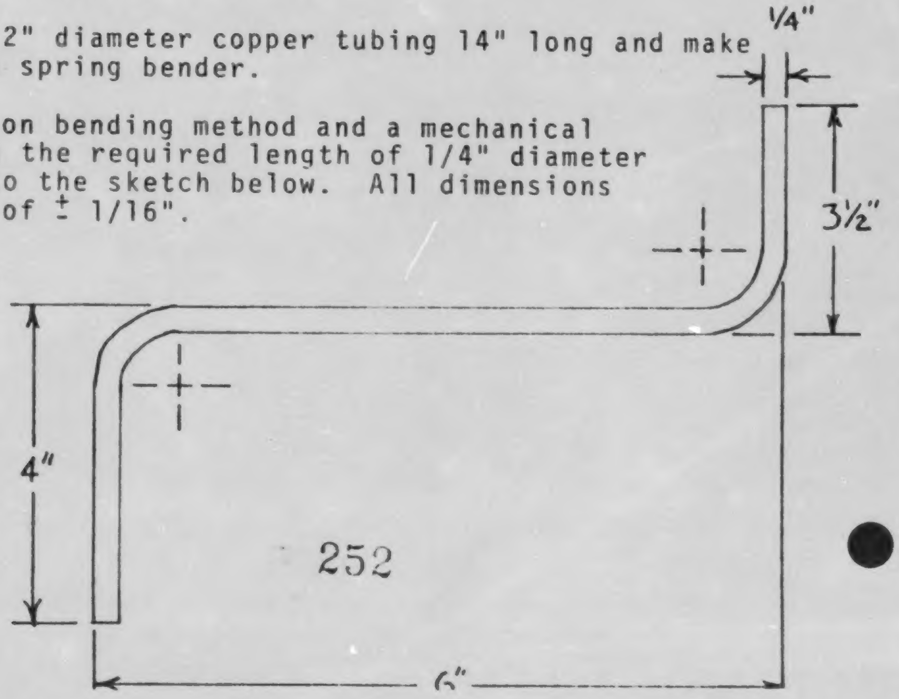
* The bend radii for the above procedures are for example only. Check the radius of the tool used to make the bend and use this radius for calculations in an actual bending task.

Lab Exercise

1. Cut a piece of 3/8" diameter copper tubing 16" long and make a 180° bend by hand method.

2. Cut a piece of 1/2" diameter copper tubing 14" long and make a 90° bend with a spring bender.

3. Using the precision bending method and a mechanical bender, calculate the required length of 1/4" diameter tubing and bend to the sketch below. All dimensions have a tolerance of ± 1/16".



Plastic pipe is very useful in plumbing where pressures and temperatures are in an acceptable range. Being more flexible than either steel or copper, it can fit quite well in irregular ditches or troughs. It is also much less expensive and therefore, highly desirable when used for an appropriate application. Its application in the Solar industry, however, is very limited.

There are three types of plastic pipes produced for home plumbing. They are PVC (Polyvinyl chloride), ABS (acrylo-mitrile butadiene-styrene), and CPVC (chlorinated polyvinyl chloride). All three can be used for cold water systems but only CPVC, rated at 100 psi at 180°F can be used for hot water systems, providing local codes permit.

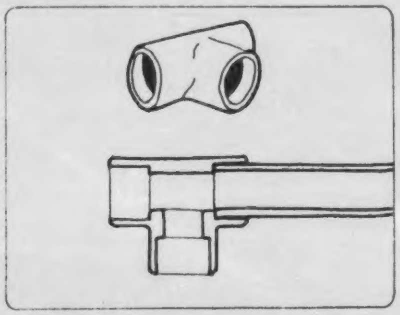
If CPVC is used with hot water systems, be sure the pressure-temperature relief valve is one rated at a pressure and temperature lower than 100 psi at 180°F.

Plastic pipe is joined using a solvent cement between the pipe and the fittings. It is beneficial and productive if the pipe and fittings are lightly sanded with emery cloth or cleaned with a PVC cleaner before the cement is applied. Once the cement is applied (to both pipe and fitting) the joint **must** be made immediately with a slight twisting motion. Do not attempt to use PVC cement at a temperature lower than 40°F.

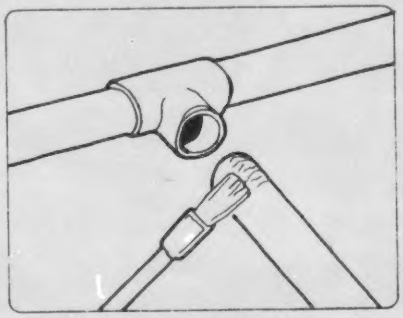
Do not attempt to pressure test PVC solvent welded piping within 16 hours of the completed piping task.

PVC fittings come in about the same sizes and confiurations as does copper fittings. The fittings are attached to the pipe with the PVC solvent. When adapting PVC to brass, copper or steel, remember the PVC threads will not stand the same torque as the metal fittings, so don't overtighten them. One way of making almost leak proof joints is to use teflon tape between the threaded fittings. Other types of sealants, such as locktite, make removal almost impossible.

Jointing - The fittings for uPVC are solvent welded, i.e., they are simply glued to the pipe. For copper, stainless steel and polythene pipe, compression fittings can be used. These are expensive, but allow one to carry out all the plumbing work without any soldering or use of a blowtorch. Copper and stainless steel can also be joined by means of capilliary ("Yorkshire") fittings and end feed fittings. These joints are made watertight by melting solder and allowing this to form a bond between the pipe and fitting. This operation requires the use of a blowtorch.



uPVC tee fitting.



Solvent welding uPVC pipe.

Expansion of Plastic Pipe - Plastic pipe can expand as much as 0.4 percent when the water flowing through it is extremely hot. When installing the pipe, then, use hangers made especially for plastic which will let it change its length without putting undue stress on it.

Types of Plastic Pipe - There are various kinds of plastic pipe that are comparable to rigid copper, and there is also one type that could be referred to as tubing. The most commonly used plastic pipes are polyvinyl chloride, better known as PVC pipe; acrylonitrile-butadiene-styrene, or ABS pipe; and chlorinated polyvinyl chloride, which you can ask for as CPVC. Of these three, only CPVC will handle both hot and cold water. Use PVC and ABS for cold water piping only. CPVC pipe is quite a bit more expensive than the other two types.

Plastic pipes generally are available in 10 foot lengths and you can **get** fittings for them just as you can for other types of pipe.

PVC, ABS, and CPVC are rigid types, but you can get polyethylene pipe. This flexible, black plastic pipe is equivalent to tubing. It is sold in 100 foot rolls and is intended for cold water use only. Its flexibility has definite advantages. You can snake it through walls, going around obstructions.

Not all poly pipe is the same; some brands cost more than others. The more expensive types are stronger and can tolerate greater amounts of water pressure. Your local water company can supply you with information about water pressure in your area and so you can be guided accordingly. It is always best, however, to give yourself the benefit of a generous safety margin. Poly is excellent for use in underground installations, such as a buried watering system for a lawn.

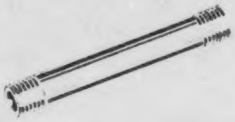
Fittings - The purpose of a fitting is to join two or more pipes. Fittings are used to extend the total length of pipe or to let the pipe change its direction. Fittings are used when you want to change from one type of pipe to another, such as joining rigid copper pipe to copper tubing. Fittings can be threaded or unthreaded. There are fittings for joining copper to steel or for connecting threaded pipe to tubing. Fittings are identified by the work they do or by their shape. A vent increaser is a fitting that increases the diameter of a vent pipe. All traps are fittings that trap sewer gases. A cleanout is a fitting that lets you get at the interior of a pipe to clean it. A tee is a fitting that presumably resembles the letter T. We also have wye fittings (Y).

Finally, there are special fittings for every type of pipe and tubing, for every kind of metal or plastic. Many of these fittings resemble each other. You can have a tee fitting for iron, and still another tee fitting for copper. So you must specify the kind of fitting you need not only by name, but also by the kind of pipe or tubing for which it is **designed**.

Metal Fittings - Metal fittings are usually, but not always, threaded. The threading can be internal or external, or both. In some instances, the pipe comes equipped with its fitting as part of the pipe structure. Soil pipe, for example, is actually constructed so that one section can fit in and be joined to another section. The joined end of the pipe, then, can be regarded as a fitting.

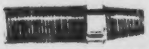
Nipples - A nipple is a short length of pipe that is either completely threaded or is threaded at both ends. The threading is external. Nipples are available in iron, brass or chrome-plated brass, and galvanized iron.

Nipples are available in three general types: close, short, and long. Close nipples are completely threaded. You can use a close nipple to join a pair of fixtures when you want the fixtures to be immediately adjacent. On a short nipple the threads do not meet. There is a space of about 1/2 to 3/4 inch near the center of the nipple that is unthreaded. Use such nipples when you want fixtures relatively close, but not butting, or touching, each other. A long nipple, such as the one shown below, is a pipe about 3 inches to 6 inches long, with external threads on the ends.



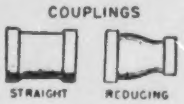
Long nipple. (Hancock-Gross)

A tapered nipple has a combination of straight and tapered threads. The tapered end is useful for fitting into almost any kind of fixture and is helpful when you want to connect pipe and fixtures when these items have different diameters.

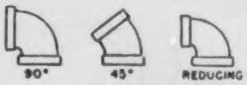


Tapered nipple.

Couplings - couplings are internally threaded fittings used to join two lengths of pipe having threaded ends. There are two types of couplings: sight and reducing. A straight coupling connects a pair of identical pipes. A reducing coupling, also known as a reducer, joins a pair of pipes having different diameters. The two basic types of couplings are illustrated below.



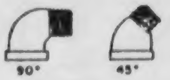
Straight and reducing couplings.



Elbows - the couplings shown below are intended for several runs of pipe. You can use elbows when the pipe is to change its direction. Elbows are internally threaded or internally/externally threaded, at both ends. Internal threads are sometimes called females; external threads, male. The angle indicated beneath the elbows in the drawings refers to the angle that will exist between the lengths of pipe when joined by the elbow. Thus a 90^{0} elbow means the two pipes will form a right angle.

The reducing elbow in the drawing lets you join two pipes having different diameters. The reducing coupling below is a 90^{0} type, but such elbows are also available to supply different angles.

The two pieces of plumbing hardware shown at the right below are street elbows. They have external threading at one end and internal threading at the other. You can use them for connecting pipe to fixtures. First, rotate the externally threaded end into the fixture. You can then connect a pipe to the other end of the street elbow. The externally threaded end of the pipe will mesh with the internally threaded end of the street elbow.

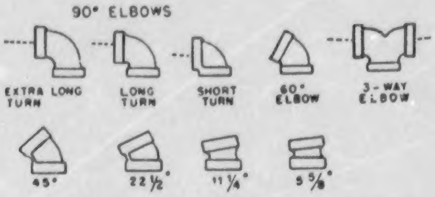


Various types of elbows. The two shown at the right are street elbows.

Drainage Elbows - when an elbow is used in a fresh water system, the pitch of the elbow is of no consequence, for the water is under pressure. An elbow that joins a pair of horizontal pipes, for example, is so designed that both sections of pipe joined by the elbow will be reasonably horizontal.

However, for drainage, as explained earlier, we depend on gravity to carry the waste to the soil stack and so drainage piping must have a downward pitch.

The illustrations on the next page are some of the more widely used drainage fittings. The dashed line represents the pitch of the threaded opening. The pitch is such that it will not interfere with the pitch of the drain pipes. Elbows are made so you can have an extra long turn, a long turn or a short turn. The purpose of the extra long turn is to avoid the possibility of a clog. The shorter turns are used where the waste is liquid. The 5 5/8^0 elbow is used where the connecting pipes are practically in line with each other. It can also be used to supply a pitch or slope of about 1 1/8 inches per foot of pipe.



Elbows for drainage pipes and fixtures.

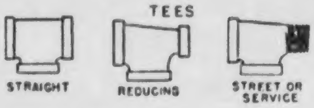
Tees - a tee is a coupling that has three openings. The openings may all be internally threaded or have a combination of internal and external threads.

Three types are shown below. The one at the left is a straight tee. You can use it when you want to join three lengths of pipe, two in a straight line and a third at right angles to them.

The tee shown in the center is a reducing tee. Use it to join one length of horizontal pipe with another length of horizontal pipe, which has a smaller diameter. As with the straight tee, it accommodates a third pipe which makes a right angle with the original tee.

The tee at the right is a street, or service, tee. It works in the same way as the street elbows previously described, but has provision for a third pipe.

Elbows, tees, and nipples can be mounted in any position. If the pipes to be joined are vertical, then the coupling hardware can be mounted so as to accommodate the pipe. If we assume that the pipe is horizontal, then the pipe entering from the left is known as the first run and the opening in the tee is called the first run opening. The first run is usually the pipe that is closest to the sewer drain. The second run opening in the tee is directly opposite the first run opening. The outlet opening is the one that permits connecting the pipe at right angles to the other two sections of pipe.

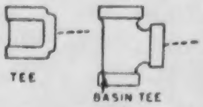


Various types of tees.

You can buy tees in which the openings are all of the same size, or with size variations among the different openings. All the openings, of course, must mesh with the pipes and fixtures with which they will connect. The following table supplies some indication of the various opening sizes that can be used in combination with a first run opening of 1 inch. This is not intended as a complete table, for you can find a much greater variation than the opening sizes listed here.

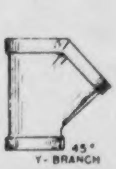
First Run Opening	Second Run Opening	Outlet Opening
1	1	1½
1	1	1¼
1	1	¾
1	1	½
1	1	⅜
1	¾	1
1	¾	¾
1	¾	½
1	½	1
1	½	¾
1	½	½

As with elbows, you can buy tees that have a pitch to accommodate the downward slope of pipes, or that fit pipes which are completely horizontal or vertical. The figure below shows a pair of tees to be used in a drainage system, with the dashed lines representing the slope of the threads. The tee connections here have the side outlet pitched upward so that the tees can be attached to pipes having an upward slope toward a fixture. For example, you could have the 5 5/8^{o} elbow attached to the drain pipe of a sink. The pipe in the elbow would lead downward and connect to the right side of the basin tee. The two other openings of the basin tee would connect to a pair of vertical drain pipes, one coming down into the upper opening of the basin tee, and the other leading down from the lower opening.



Tees for use in a drainage system.

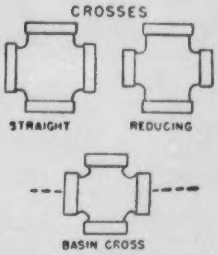
The Y-Branch - the Y-branch shown below is a coupling for joining three pipes, two of which are in the same straight line and the third entering at an angle of 45^{o}. Couplings of this kind are often used for connecting waste pipes to the soil stack.



Y-branch accommodates pipe entering the coupling at a 45° angle.

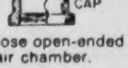
Crosses - Still another type of coupling is the cross; two examples of which are shown below. Crosses come in two types: straight or reducing. The straight cross is used for connecting four pipes having identical diameters. The reducing cross is used when one pair of pipes has a smaller diameter than the other. For example, the openings for the first and second runs can be the same; while the two outlets openings can also have matched diameters; but somewhat different from those for the first and second runs.

Crosses are mainly used in drainage and venting systems. Thus, three of the openings can be used for joining drain pipes, and the fourth as the opening for a vent.

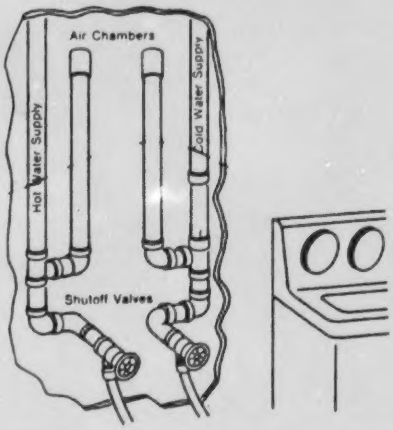


Crosses are couplings for four pipes. The basin cross is pitched for use in drainage systems.

Caps - a cap is hardware used for closing the end of a pipe. Air chambers are sections of pipe about 1 1/2 feet long, closed at one end with a cap. You can also use a cap if you have a section of pipe which you wish to close off when the pipe openings is not to be used. The advantage of a cap under these circumstances is that it keeps unwanted debris from falling into the pipe. It also keeps the open section of pipe from being used as a nest by insects.

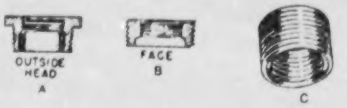


Cap is used to close open-ended pipe or in connection with an air chamber.

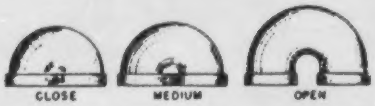


Air chambers prevent water hammer.

Bushings - busings are threaded inside and out. Assume you have two pipes, both with threaded ends but with different diameters. You can insert the smaller-diameter pipe into the inside threaded portion of the busing and the larger diameter pipe to the outside threaded portion. You can also use this technique to connect fittings, faucets, or values. Thus, by using a suitable bushing, you can connect 1 inch pipe to pipe of a smaller or larger diameter. Bushings have heads which are hexagonal or octagonal so you can tighten them with a wrench. These are known as outside head bushings, but you can also get straight face bushings which do not have the outside head feature. The straight face bushing may be flared at one end; or it may resemble a short nippe which, unlike a nipple, is threaded both inside and out.



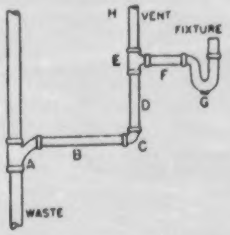
Return Bends - a return bend is used when a pipe must double back on itself. Various types of return bends are available, giving you some control over the positioning of the pipes relative to each other. With a close return bend the pipes will be almost touching; with the medium they will be further away; while with an open return bend you will get maximum separation. Return bends are used for very special applications in plumbing and it would be unusual to find them in a home plumbing system.



Return bends.

Use of Fittings in **Piping Assembly** - the purpose of fittings is to let you connect piping so that water can be delivered to various fixtures; or to connect piping so as to remove waste. There are some precautions, however. For the water supply system the fittings must not leak, something they can do rather easily, since the water is under pressure. For the drain system; the fittings must not interfere with the downward flow of waste; and so they must have the correct pitch for horizontal piping. And since water also flows through drain pipes, the fittings must be watertight.

The figure below shows the order in which we would assemble piping so as to connect a fixture to a waste pipe. The waste pipe could, in turn, be connected to the soil stack or, more probably, to more fixtures.



Use of fittings in connecting piping from a waste line to a fixture. Y branch (A); horizontal drain pipe (B); 90° elbow (C); vertical drain pipe (D); tee (E); horizontal drain pipe (F); trap (G).

The letters used in the drawing are arranged in the order of assembly. We would start with Y-branch A, screw threaded pipe B into the Y-branch, and then attach elbow C to the threaded end of pipe B. Next, we would screw in pipe D and thread tee E onto pipe D. With the addition of pipe F, trap G, and vent H, the job would be done.

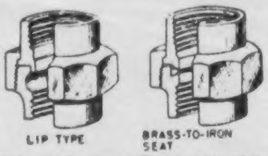
This doesn't mean you must always follow this procedure. You may find it convenient or necessary to alter the assembly routine. However, if you are using threaded rigid piping, this is a good pictorial of the completed work.

There is one serious drawback to the plumbing setup shown in this drawing; although it will work well. As an example, suppose pipe B has developed such a serious leak that replacement is the only solution. Consider the difficulty of removing that pipe. If you try to turn it with a pipe wrench, you will only succeed in forcing it more tightly into fittings A or C, depending on which way you turn. The only way to get at pipe B is to remove the trap G, then pipe F, then fitting E, then pipe D, and finally fitting C.

And not only do you have all the work of disassembling this section of the plumbing system, but when the replacement for pipe B is in position, you must first start putting the system back into working order again. All of this means quite a bit of work if you do it yourself, and a rather steep bill if you decide to have your plumber do it.

Unions - the piping situation just described indicates that plumbing is more than just a matter of connecting pipes. You must consider that you may need to replace some part, whether a pipe, a fitting, or a fixture.

A union is a fitting that will let you disconnect pipes with the least amount of trouble. The piping leading from your hot water system, for example, is a potential troublemaker. Essentially, a union is a three-part device. One part of the union threads onto the run-in pipe while another part threads onto the run-out pipe. The third part, a specially designed nut, holds the first two parts together and can be made to pull them together.



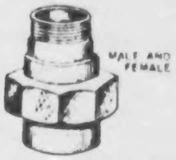
Commonly used unions. Some parts of the union may be brass to prevent rusting.

The most commonly used union is the lip type, shown in a cutaway view in the above figure, along with another type that works the same way and is almost identical in construction. The upper half and the lower half of each is threaded internally. One pipe fits into the upper half, another pipe into the lower half. All you need do now is to tighten the nut to make a secure, tight joint. However, you can get water leakage at a union, so use piping compound, or Teflon all-purpose pipe dope to get a watertight connection.

The two pipes that would be used in connection with the above unions are externally, or male, threaded at their ends. However, you can use the union shown below if one of the pipes is internally threaded at its end and the other pipe is externally threaded. Other than that, the union below is used in exactly the same way as the previous two unions. Connect the pipes and then use a wrench to tighten the nut. If, at some time in the figure, you want to remove the connecting pipes, just turn the nut in a counterclockwise direction.

Some unions are equipped with a nut made of brass or may have a brass seat. This makes it easier to loosen the union since brass will not rust.

The figure below shows still another type of union, one which is rarely used in home plumbing systems. The union is internally threaded and consists of two halves which can come apart. Each half is threaded onto the pipes to be connected. The union is held together and tightened by means of nuts and bolts.



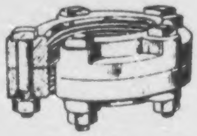
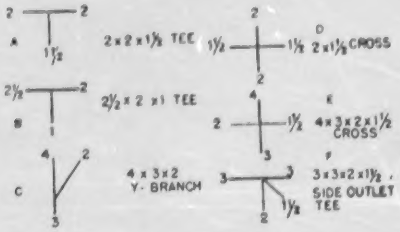


Fig. 3-28.
Nut union.

Symbolic Drawings for Fittings - Drawings using plumbing symbols were described earlier. Such drawings are quite simple, and when you get accustomed to them, it will be easier for you to plan your plumbing system on paper. And if your plumber shows you such a drawing, you will at least know what he is talking about.

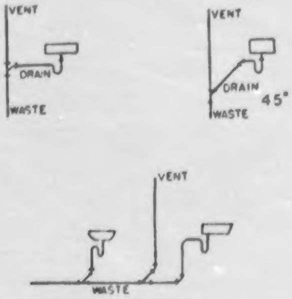
The figure below shows how to use plumbing symbols for fittings. Drawing A is that of a tee. For tees and Y-branches, the larger run size is given first, then the smaller run, and finally the outlet. In drawing A we have a 2 inch pipe that is joined to another 2 inch pipe with both connected to a 1 1/2 inch pipe through a tee fitting. Drawing B shows a 2 1/2 inch pipe connected to a 2 inch pipe, joined to a 1 inch pipe through a tee. Note that except for labeled dimensions, drawings A and B are identical.

Drawing C is a Y-branch. Here we have a 3 inch pipe connected to a 4 inch pipe while the branch pipe is 2 inch. Drawings D and E use cross fittings, while drawing F has a side outlet tee. A side outlet tee is one having an opening for an additional pipe coming in at an angle.


A
2
2
1½
2×2×1½ TEE
B
2½
2
1
2½×2×1 TEE
C
4
2
3
4×3×2
Y- BRANCH
D
2
1½
1½
2
2×1½ CROSS
E
4
2
1½
3
4×3×2×1½
CROSS
F
3
3
2
1½
3×3×2×1½ ,
SIDE OUTLET
TEE

Symbolic drawings for some fittings.

Fitting symbols are used in conjunction with other plumbing symbols, as in the figure below. Dimensions can be used on such drawings or may be omitted. In the center drawing: for example, the only dimension information supplied is that the Y-branch has a 45° angle.

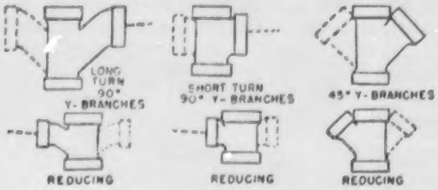

VENT
DRAIN
WASTE
VENT
DRAIN
45°
WASTE
VENT
WASTE

Symbolic drawings showing use of fixture, pipe, and fitting symbols

Cast Iron Drainage Fittings - the purpose of a drainage fitting is to join two sections of drainage pipe, while permitting entry by one or more pipes. The entering pipes may make a 90^{0} angle with the drainage pipes and so the entering pipes look horizontal. However, they are not, for they must have a pitch to permit the flow of waste into the drainage pipe.

The figure below illustrates some cast iron drainage Y-branches. The single horizontal dashed line indicates the pitch of the entering pipe. The dashed outlines show the possibility of having two entering pipes instead of just one. Y-branches may be long turn or short. A long turn simply means that the extension of the Y-branch arm is longer than that of a short turn.

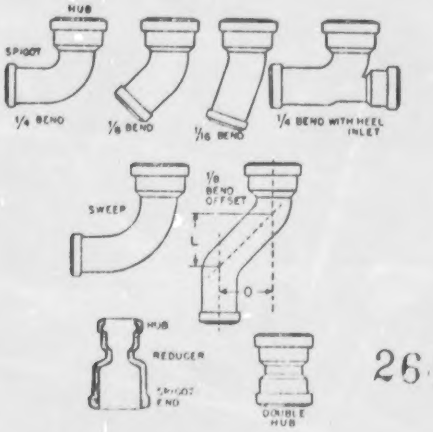
Although the Y-branches shown in the drawings are 45^{0} or 90^{0}, they are also available as long sweep quarter bends, or sixth, eighth, or sixteenth bends.


LONG TURN 90° Y-BRANCHES
SHORT TURN 90° Y-BRANCHES
45° Y-BRANCHES
REDUCING
REDUCING
REDUCING

Cast iron Y-branches for drainage.

Soil Pipe Fittings - Just as in the case of iron pipe described earlier, soil pipe fixtures can also have a hub and spigot end. In effect, then, you can regard the soil pipe fixture as a very short length of soil pipe, but with a bend in it ranging up to 90^{0}.

The figure below shows various types of fittings that can be used with soil pipe. The 1/4 bend is just another way of describing a fitting to join pipes that are at right (90^{0}) angles to each other. The 1/8 bend fitting is for pipes that are at an angle of 45^{0}, and the 1/16 bend for pipes at an angle of 22 1/2^{0}. Note that the 1/4 bend fitting also has provision for the entry of another pipe, an arrangement that is sometimes called a heel inlet.


HUB
SPIGOT
1/4 BEND
1/8 BEND
1/16 BEND
1/4 BEND WITH HEEL INLET
SWEEP
1/8 BEND OFFSET
L
O
HUB
REDUCER
SPIGOT END
DOUBLE HUB

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

GLAZING MATERIALS

STUDENT MATERIAL

GLAZING MATERIALS

Glass and plastic glazings trap heat within specific volumes of solar systems. This may be within the solar collectors in active systems or within greenhouses in passive systems. To determine the heat-trapping ability of a particular glazing, the fate of the solar radiation which impinges on its surface must be known. This radiation may be absorbed, transmitted, or reflected. All three processes occur simultaneously; the relative importance of each is critical in determining the effectiveness of the glazing. Consideration must also be given to the relative amount of absorption, transmission, and reflection of longwave (heat) radiation. The desirable characteristics of a glazing are illustrated in figure 4-1 and, briefly stated, are the following:

> High transmittance of solar radiation, so that solar energy will pass through the glazing to an absorber material.
>
> High reflectance of longwave radiation emitted by the absorber so that energy will be reflected back to the absorber.
>
> Low absorptance of all radiation so the glazing will not rise in temperature to a point of physical and chemical degradation and will not lose heat by conduction, convection, or reradiation.

Solar transmittance data for glazings are readily available. Longwave reflectance data are not, but reflectance may be estimated because of its relationship with transmittance and absorptance. Since absorptance by glazings is usually relatively low, high longwave reflectance is usually indicated by low longwave transmittance.

To perform well for an extended period of time, a glazing must have the following characteristics: A) resistance to surface erosion or marring from wind, dust, and hail; B) resistance to change from UV radiation; C) resistance to degradation by high temperatures and thermal cycling.

Glazings also have a protective role in that they shield the underlying surfaces from exposure to the outdoor atmosphere. Impact resistance is the major factor in considering this role of glazings. The environmental response properties given above will also affect the effectiveness of protection over the lifetime of glazing.

Glass

Glass has adequate solar transmittance and good resistance to weathering. The lower the iron content of glass, the higher is the solar transmittance. Disadvantages of glass are its low impact resistance, which makes it susceptible to breakage by hailstones or vandals, and high weight, which adds to the difficulty

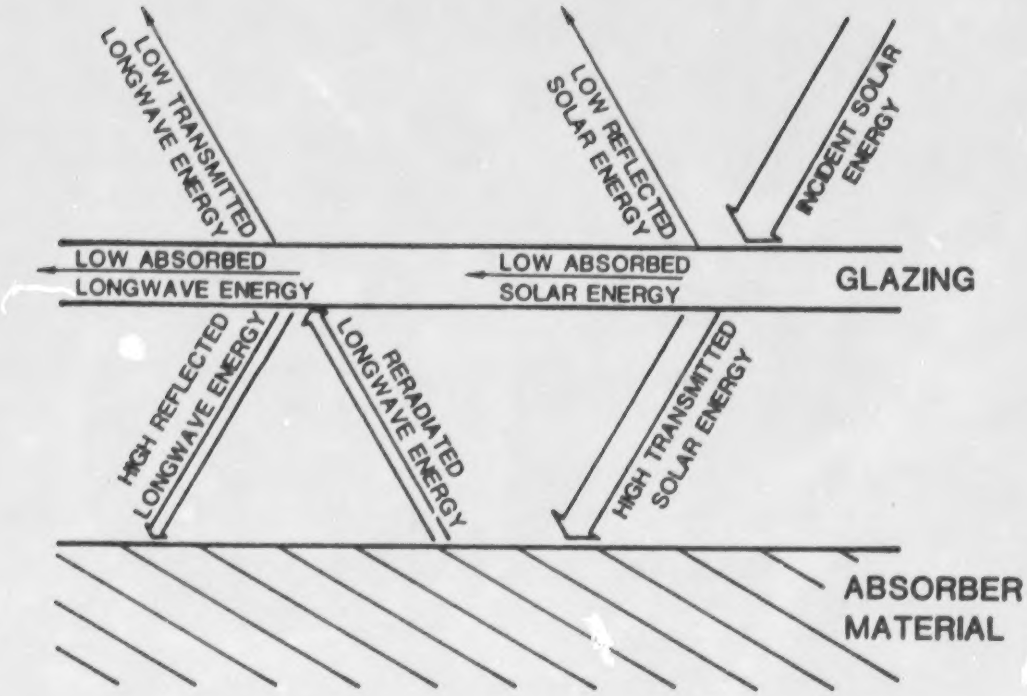

LOW TRANSMITTED LONGWAVE ENERGY
LOW REFLECTED SOLAR ENERGY
INCIDENT SOLAR ENERGY
LOW ABSORBED LONGWAVE ENERGY
LOW ABSORBED SOLAR ENERGY
GLAZING
HIGH REFLECTED LONGWAVE ENERGY
RERADIATED LONGWAVE ENERGY
HIGH TRANSMITTED SOLAR ENERGY
ABSORBER MATERIAL

Figure 4-1. Desired effect of glazing on radiation distribution

of handling and installation. Also, while glass transmits very little longwave radiation, it absorbs longwave radiation, leading to heat loss.

Plastics

Plastics are light weight and have better shatter resistance than glass. Optical and weathering characteristics are quite variable among the plastics, depending on composition of the base polymer, plasticizers, stabilizers, and other additives. Properties also vary with thickness of plastics, which range from thin, flexible films to thick, rigid sheets. Plastics have low maximum operating temperatures in comparison with glass. A more detailed discussion of the properties of plastics and considerations for their use as glazings are given in the next section. This is followed by a list and discussion of numerous specific plastics which might be considered for solar applications.

Advantages and disadvantages of general classes of glazings most suitable for use in solar systems are presented in Table 4-1. However, differences in physical, optical, and weathering properties exist within each class as well as among the classes. This is evident from the properties of specific glazings presented in Tables 4-2 through 4-8.

Plastics are synthetically produced polymers, which by varying the formulations and conditions of production, can have a wide variety of properties. Consequently, they have many applications. In solar heating systems, plastics have several miscellaneous functions in addition to glazing (Table 4-9).

Plastics may be formulated to have specific characteristics important in solar systems, such as mechanical properties (strength, rigidity, impact resistance) and degradation properties (resistance to fire, radiation, and heat). However, assigning meaningful values to the properties of interest is very difficult because a) the properties depend on temperature and b) the properties change with time as the material is used. As a result, there is no simple maximum use temperature for a plastic that is likely to apply to all or even most of the properties that are important in elevated temperature applications (Agranoff 1979). Ideally, the effect of time and temperature on all properties for designing components and estimating performance would be known. Unfortunately, such comprehensive information is not available. However, Underwriters' Laboratories have compiled temperature indices for mechanical and electrical properties (Table 4-10). These indices are temperatures at which plastics could be maintained for at least one year before failure would be expected.

Table 4-1. Advantages and disadvantages of general classes of glazing

GLAZING	ADVANTAGE	DISADVANTAGE
Glass	Excellent Weathering Resistance	Low Impact Strength High Density Poor Thermal Stress Resistance
Acrylic	Good Insulator High Impact Strength Good Weathering Resistance	Low Softening Point Distortion when Heated Surface Abrasion
Fluorinated Ethylene-Propylene	High Chemical Stability Excellent Weathering Resistance	High Longwave Transmittance
Glass Fiber-Reinforced Polyester	Lightweight High Strength High Impact Resistance High Heat Resistance Near Opacity to Longwave Radiation High Durability	Poor Weathering (Surfacing with PVF Improves Resistance to Surface Erosion)
Polycarbonate	Good Insulator Highest Initial Impact Strength of All Plastics	Low Mar-Resistance Mar Resistant Types Do Not Weather Well Surface Deterioration By Radiation/moisture Results in Gradual Impairment of Strength High Cost
Polyester	Surface Hardness Low Cost	High Longwave Transmittance UV Degradation Unless Coated
Polyethylene	Light Weight Flexible Low Cost	Short Lifetime High Longwave Transmittance Wind and Temperature Sagging
Polyvinylfluoride	High Chemical Stability High Resistance to Abrasion Excellent Weathering Resistance Low Cost	High Longwave Transmittance

Table 4-2. Properties of glass glazing

PROPERTY	GLAZING Generic	 Heliolite Low-Iron Tempered Translucent	 Sunadex Rolled 0.01% Iron Oxide Transparent	 ASG Lo-Iron Tempered 0.05% Iron Oxide Transparent
Thickness		0.125 to 0.188 in		
Solar Transmittance	84 to 91%	89 to 90%	91%	88 to 89%
Longwave Transmittance	2%			
Maximum Operating Temperature		Continuous 500°F	Continuous 400°F	400°F
Linear Expansion Coefficient		$9 \times 10^{-6}/^\circ F$	$5 \times 10^{-6}/^\circ F$	$5 \times 10^{-6}/^\circ F$
Weathering Characteristics	Excellent	No UV Degradation; Surface Weathering: Nil	Excellent	Excellent
Reference	Montgomery (1978)	Solar Age Magazine (1979)	Solar Age Magazine (1978)	Solar Age Magazine (1978)

Table 4-3. Properties of acrylic glazing

	GLAZING			
PROPERTY	Generic	Plexiglas-G	Acrylite Double Glazing	Flexigard Polyester Acrylic Composite
Thickness			Two 0.04-in sheets separated by 0.6 in	0.008 in
Solar Transmittance	80 to 90%	92%	83%	88 to 90%
Longwave Transmittance	2%			
Maximum Operating Temperature		180 to 200°F	160°F	275°F
Linear Expansion Coefficient		$41 \times 10^{-6}/°F$		
Weathering Characteristics	Average to Good	Good		Exceptional stability to weathering over a 15-year period
Reference	Montgomery (1978)	Knudtson (1978)	Cyro Industries (1978?)	3M Company

Table 4-4. Properties of fluorinated ethylene-propylene glazing

	GLAZING		
PROPERTY	Teflon FEP	Teflon FEP	Teflon Film
Thickness		0.20 in	0.001 in
Solar Transmittance	90 to 92%	98%	96%
Longwave Transmittance	25 to 26%		
Maximum Operating Temperature		400°F	400°F
Linear Expansion Coefficient		$6\times10^{-6}/°F$	
Weathering Characteristics	Fair to Good	Excellent	After 15-year exposure in Florida, light transmission was unchanged at 93% and tensile strength was unchanged
Reference	Montgomery (1978)	Knudtson (1978)	Plastic Products and Resins Department

Table 4-5. Properties of glass fiber reinforced polyester glazing

	GLAZING			
PROPERTY	Fiberglass	Sunlite	Filon with Tedlar Surface	Lascolite
Thickness		0.04 in	0.03 to 0.08 in	0.04 in
Solar Transmittance	77 to 87%	85 to 90%	89%	86%
Longwave Transmittance	0.1 to 0.3%	10%		
Maximum Operating Temperature		Continuous 200°F	Continuous 200°F	
Linear Expansion Coefficient		$14\times10^{-6}/^{\circ}F$	$18\times10^{-6}/^{\circ}F$	14 to 18 $\times10^{-6}/^{\circ}F$
Weathering Characteristics	Fair to Good	Good; 12-mo exposure in Florida resulted in 1% transmission loss	Resists UV degradation	Good
Reference	Montgomery (1978)	Solar Components Division, Solar Age Magazine (1979), Knudtson (1978)	Solar Age Magazine (1979)	Knudtson (1978)

Table 4-6. Properties of polycarbonate glazing

	GLAZING			
PROPERTY	Generic	Lexan Double Glazing	Poly-Glaz	Lexan Film
Thickness			0.03 to 0.5 in	0.005 to 0.007 in
Solar Transmittance	73 to 84%	79%	85%	93 to 94%
Longwave Transmittance	2%			
Maximum Operating Temperature		Continuous 220°F	250°F	270°F
Linear Expansion Coefficient		$37 \times 10^{-6}/°F$	$37 \times 10^{-6}/°F$	
Weathering Characteristics	Poor to fair	No surface weathering after 4 years, 2% loss in light transmission after 4 years	Slight yellowing after 5 years	
Reference	Montgomery (1978)	Solar Age (1979)	Solar Age (1979)	Copper Development Association (1978)

Table 4-7. Properties of polyester and polyethylene glazing

	GLAZING		
PROPERTY	Polyester Film	Mylar Polyester	Polyethylene Film
Thickness		0.003 to 0.014 in	0.020 in
Solar Transmittance	80 to 87%	85%	92%
Longwave Transmittance	20 to 21%		80%
Maximum Operating Temperature		300°F	
Linear Expansion Coefficient		$15\times10^{-6}/^{\circ}F$	
Weathering Characteristics	Fair to good	Excellent (coated)	Poor
Reference	Montgomery (1978)	Knudtson (1978)	Knudtson (1978)

Table 4-8. Properties of polyvinyl fluoride and polyvinylidene fluoride glazing

	GLAZING		
PROPERTY	Tedlar Polyvinyl Fluoride	Tedlar Polyvinyl Fluoride	Kynar Polyvinylidene Fluoride
Thickness	0.004 in	0.030 in	0.003 to 0.02 in
Solar Transmittance	92 to 94%	93%	93%
Longwave Transmittance		43%	
Maximum Operating Temperature	Continuous 225°F	325°F	Continuous 275°F
Linear Expansion Coefficient	$15 \times 10^{-6}/^{\circ}F$	$24 \times 10^{-6}/^{\circ}F$	$75 \times 10^{-6}/^{\circ}F$
Weathering Characteristics	After 5 year exposure in Florida, film retained 95% of original transmissivity and half of original strength and toughness	Excellent	Exceptionally stable to UV radiation, moisture, temperature fluctuation and heat sagging
References	DuPont (1975)	Knudtson (1975)	Westlake Plastics Company, Pennwalt Corporation (1977)

Table 4-9. Uses of plastics in solar heating systems

PLASTIC	USE
Acrylonitrile-Butadiene-Styrene	Collector Hardware
Acrylic (including Polymethylmethacrylate)	Glazing Lenses in Concentrating Collectors Substrate in Mirrors
Cellulose Acetate Butyrate	Substrate in Mirrors
Fluorinated Ethylene-Propylene	Glazing Honeycomb Structure Substrate in Mirrors
Nylon	Collector Hardware
Polybutylene	Plumbing
Polycarbonate	Glazing Honeycomb Structures
Polyester (including Glass-Reinforced)	Glazing Honeycomb Structures Storage and Hot Water Tanks
Polyethylene	Glazing Storage and Hot Water Tanks Collector Housing
Polyethylene Terephthalate	Honeycomb Structure Substrate in Mirrors
Polyimide	Honeycomb Structure
Polypropylene	Absorber Plate, Plumbing
Polysulfone	Plumbing Component
Polytetrafluoroethylene	
Polyvinyl Chloride (including Chlorinated Polyvinyl Chloride)	Plumbing
Polyvinyl Fluoride	Glazing Honeycomb Structure Substrate in Mirrors
Polyvinylidine Fluoride	Glazing

Table 4-10. Underwriters' Laboratories temperature indices for plastics[a]

PLASTIC	TEMPERATURE INDEX[b] (°F)
Acrylonitrile-Butadiene-Styrene	120 to 200
Acrylic (including Polymethylmethacrylate)	120 to 160
Fluorinated Ethylene Propylene	300
Nylon	150 to 260
Polycarbonate	150 to 260
Polyester Thermoplastic	130 to 280
Polyester Thermoset (including Glass-Reinforced)	210 to 320
Polyethylene	120
Polyethylene Terephthalate	220
Polyimide	390 to 410
Polypropylene	120 to 240
Polysulfone	280 to 340
Polyvinyl Chloride	120 to 220

---

[a] Data from Agranoff, J. (ed.) 1979. Modern Plastics Encyclopedia, 56(10A). McGraw-Hill Inc., New York, NY.

[b] The temperature index is the temperature at which plastics could be maintained for at least a year before failure would be expected.

Rigid plastics, which can support loads and stresses much as metals do, have mechanical properties that differ from those of metals. When put under a load at ambient temperatures, both metals and plastics deform. When the load is allowed to remain, plastics continue to deform at a slow rate indefinitely, whereas metals do not deform further. The continuing deformation is called creep; the higher the creep resistance, the less the plastic will deform over time.
Thermal expansion of plastics is much greater than for metals, with linear expansion coefficients (Table 4-11) being 2 to 10 times as large as those of metals. Chapter 2 Basic Concepts discusses the use of these data in selecting a glazing compatible with the other materials in the system.

Plastics are classified into two general categories based on changes in mechanical peoperties with increasing temperature. Thermoplastics soften when temperature is increased. Thermosets, which have crosslinking among polymer chains, do not melt. When temperature is increased they undergo surface deterioration, cracking, and/or warping due to oxidation and thermal degradation.

In contrast to the reversible thermal expansion at moderate temperatures, plastics may shrink irreversibly when exposed to high temperatures. Plastics are stable with respect to shrinkage at temperatures below which they are annealed, i.e., heated after production.

Chemical degradation of plastics may occur through several mechanisms, including dissolving, chemically reacting, swelling, softening, and cracking. Resistances of plastics to chemical degradation are presented in Tables 4-12 and 4-13.

Characteristics of the ambient atmosphere which may degrade plastic are humidity, UV radiation, and air pollutants. Resistances to degradation by sunlight and high humidity are presented on Table 4-14.

Specific solid plastics that have been used in solar heating systems are described below (compiled from Agranoff 1979).

Acrylonitrile-butadiene-styrene (ABS, thermoplastic) plastics are copolymers of three compounds which may be blended in various proportions to emphasize different properties. Chemical and heat resistance and strength are provided by acrylonitrile. Impact strength and toughness are provided by butadiene. Rigidity, gloss, and easy processibility are provided by styrene. ABS has low UV resistance if it is not protected or stabilized. Protection may be provided by using an acrylic film or layer, painting, or incorporating resin stabilizers.

Table 4-11. Thermal expansion of plastic resins and molding compounds[a]

PLASTIC	LINEAR EXPANSION COEFFICIENT ($10^{-6}/^{\circ}F$)
Acrylonitrile-Butadiene-Styrene	36 to 72
Acrylic	22 to 50
Polymethylmethacrylate	28 to 50
Cellulose Acetate Butyrate	61 to 94
Nylon 6	17 to 50
Nylon 66	44
Polybutylene	71 to 84
Polycarbonate	35 to 38
Polyethylene	56 to 72
Polyethylene Terephthalate	36
Glass Reinforced	16
Polyimide	25 to 31
Polysulfone	29 to 31
Polytetrafluoroethylene, Glass Reinforced	43 to 56
Polyvinyl Chloride	28 to 56
Chlorinated	38 to 43
Polyvinylidene Fluoride	48
Copper (for comparison)	9

---

[a] Data from Agranoff, J. (ed.) 1979. Modern Plastics Encyclopedia, 56(10A). McGraw-Hill Inc., New York, NY.

Table 4-12. Resistance of plastic films to degradation by fluids[a]

PLASTIC	FLUID				
	STRONG ACID	STRONG ALKALIES	GREASE OILS	ORGANIC SOLVENTS	WATER
Acrylonitrile-Butadiene-Styrene	G to F	G	G	F to P	G
Acrylic Polymethylmethacrylate	G	G	P	-	G
Cellulose Acetate Butyrate	P	P	G	P	G
Fluorinated Ethylene-Propylene	G	G	G	G	G
Nylon 6 Extruded	P	F	G	G	G to P
Polycarbonate	G	P	G	G to P	G
Polyethylene	G	G	G to P	G to F	G
Polyethylene Terephthalate	G	P	G	G	G
Polyimide	G	P	G	G	G
Polypropylene	G	G	G	G	G
Polysulfone	G	G	G	P	G
Polytetrafluoroethylene	G	G	G	G	G
Polyvinyl Chloride	G	G	G	G to P	G
Polyvinyl Fluoride	G	G	G	G	G
Polyvinylidene Fluoride	G	G	G	G	G

---

[a] Data from Agranoff, J. (ed) 1979. Modern Plastics Encyclopedia, 56(10A). McGraw-Hill Inc., New York, NY.

G = Good F = Fair P = Poor

Table 4-13. Resistance of plastics to degradation by heat transfer fluids and other chemicals[a]

PLASTIC	Commercial Antifreeze	Diethylene Glycol	Ethylene Glycol	Freon 11	Freon 12	Freon 21	Freon 22	Freon 113	Freon 114	Freon, other	Glycerol	Methanol	Propylene Glycol	Silicone Oil	Solder Flux	Sulfur Dioxide	Hydrochloric Acid (Concentration % in water)	Sulfuric Acid (Concentration % in water)
Acrylonitrile-Butadiene-Styrene			9									9			9		9(10)	9(10)
Acrylic												2					2(38)	1(98)
Cellulose Acetate Butyrate		5	9		7		1		9		9		9	9		6	4(10)	8(10)
Fluorinated Ethylene Propylene								9									8(20)	9(30)
Nylon	3		9	9	9	9	9			9		9				2	2(10)	2(30)
Polybutylene			9									9		9			9(38)	2(98)
Polycarbonate			9									9			9		9(10)	9(10)
Polyester	9		9							9		9			9		9(10)	9(10)
Polyethylene			9								9	9			9		9(10)	9(30)
Polyethylene Terephthalate																		
Polyimide										9							4(10)	4(10)
Polypropylene			9								9	8					9(30)	9(50)
Polysulfone			9														9(10)	
Polyvinylidene Fluoride																	9(20)	9(98)

[a]Data from Agranoff, J. (ed.) 1978. Modern Plastics Encyclopedia, 55(10A). McGraw-Hill, New York, NY.

9 No effect	6 Warped	3 Crazed
8 Discolored	5 Softened	2 Attacked
7 Swelled	4 Surface Attacked	1 Dissolved

Table 4-14. Resistance of plastic films to degradation by sunlight and high relative humidity[a]

PLASTIC	RESISTANCE TO DEGRADATION BY SUNLIGHT	RESISTANCE TO DEGRADATION BY HIGH RELATIVE HUMIDITY
Acrylonitrile-Butadiene-Styrene	F	G
Acrylic Polymethylmethacrylate	G	G
Cellulose Acetate Butyrate	G	G
Fluorinated Ethylene-Propylene	G	G
Nylon	F	G to P
Polycarbonate	F	G
Polyethylene	F	G
Polyethylene Terephthalate	F	G
Polyimide	G	G
Polypropylene	F	G
Polysulfone	P	G
Polytetrafluoroethylene	G	G
Polyvinyl Chloride	G to F	G
Polyvinyl Fluoride	G	G
Polyvinylidene Fluoride	G	G

[a] Data from Agranoff, J. (ed.) 1979. Modern Plastics Encyclopedia, 56(10A). McGraw-Hill Inc., New York, NY.

G = Good F = Fair P = Poor

Acrylic plastics are polymers and copolymers of acrylate and methacrylic esters. Polymethyl methacrylate (PMMA, thermoplastic) is the most important acrylic plastic. Acrylics have properties of outstanding optical quality and high resistance to sunlight and environmental agents.

Cellulose acetate butyrate (CAB, thermoplastic) is one of a class of plastics manufactured by chemical modification of cellulose. It is tough, strong, stiff, and hard, and has good weatherability. CAB sheet can be laminated with aluminum foil or can be vacuum metallized.

Fluorinated ethylene propylene (FEP, thermoplastic) has good weatherability and is chemically inert. It has lower wear resistance, creep resistance, and tensile strength than most other engineering plastics.

Nylons (thermoplastic) are polyamide resins. They are tough, durable, have good abrasion resistance, have good chemical resistance except to strong acids and to oxidizing agents, and have good heat resistance.

Polybutylene (thermoplastic) plastics are synthesized from butene-1 monomer and may exist in a variety of crystalline forms. They are tough, have high creep resistance, and are resistant to stress cracking, abrasion, and heat. They are resistant to most acids and bases below 200°F, but are partially soluble in chlorinated and aromatic hydrocarbons above 140°F. They are very versatile for plumbing applications when compatible fluids are used.

Polycarbonate (thermoplastic) plastics are derived from bisphenol A and may contain other phenols for property modification. Properties include high impact strength, high dimensional stability, high rigidity, low water absorption, good creep resistance, and wide operational temperature range. Coatings are used to increase chemical resistance and weatherability.

Polyester (thermoset) is a condensation product of an unsaturated dibasic acid, such as maleic anhydride or fumaric acid, and a glycol, such as propylene glycol or ethylene glycol. Most polyesters are reinforced with glass, graphite, or other fiber. They have highly variable properties depending on their formulation, and can be made chemical, fire, or weather resistant by selection of appropriate ingredients. Shrinkage is a major disadvantage of polyesters, but may be lessened by the addition of thermoplastics.

Polyethylene (thermoplastic) plastics are a class which contains hundreds of compounds, which have different structures, different densities, and highly variable properties. Low density films have properties of chemical inertness, strength, clarity, flexibility and low cost.

Polyethylene Teraphthalate (thermoplastic) has high strength, toughness, and clarity. It is resistant to weak acids and bases and most solvents.

Polyimide (thermoplastic and thermoset) is very resistant to heat degradation, creep, and combustion. The coefficient of thermal expansion is low in comparison with other plastics. Polyimide is unaffected by many solvents and chemicals, but is attacked by concentrated inorganic acids and dilute alkalies.

Polypropylene (thermoplastic) plastics are resistant to heat and moisture. They are resistant to many chemicals at elevated temperatures, including mineral acids and bases up to 140^{o}F and organic solvents up to 175^{o}F.

Polysulfone (thermoplastic) has high transparency, excellent heat resistance, excellent oxidation resistance, and good chemical resistance. Polysulfone has good resistance to acids, bases, and salt solutions; good resistance to detergents, oils, and alcohols; but is attacked by polar organic solvents. It is dimensionally stable with respect to heat and moisture. Transparent and fiber-filled types are used for corrosion-resistant piping in chemical processing and pollution control equipment.

Polytetrafluoroethylene (PTFE, thermoplastic) has high impact strength, good weatherability, and outstanding resistance to chemical attack. It is insoluble in all organics except a few fluorinated solvents. In comparison with other engineering plastics, polytetrafluoroethylene has low wear resistance, creep resistance, and tensile strength.

Polyvinyl chloride (PVC, thermoplastic) is a versatile, economic plastic with resistance to water, acids, alkalies, oxidation and weathering. It is stable over long periods of time. Chlorinated PVC is more stable at higher temperatures than PVC and, therefore, can be used in piping for residential hot water systems. Only certain formulations can be used with organic heat transfer fluids.

Polyvinyl fluoride (thermoplastic), available as a film, has good resistance to abrasion, staining, and weathering.

Polyvinylidene fluoride (thermoplastic) is resistant to attack by most solvents and chemicals. It has good weathering resistance. It has greater wear resistance, strength, and creep resistance than other fluoroplastics such as polytetrafluoroethylene and fluorinated ethylene propylene.

Compatibility and Degradation

The results of the trapping of heat by glazing are an increase in the temperature of the system and exposure of glazing and associated materials to high temperatures. Glazing may also be exposed to the outdoor atmosphere, to high humidity, and to outgassing products from seals, sealants, and insulation. During normal operation, it may be in contact with seals, sealants, wood, metal and plastic. During abnormal conditions in active systems, the glazing may come in contact with the absorber plate and the heat transfer fluid.

Incompatibility of polymers has been observed in solar heating systems. Local fogging of cover plates has been noted when there was contact between EPDM rubber and polycarbonate glazing (Skoda and Masters 1977). One possible cause is the incompatibility among plasticizers and polymers. Any given plasticizer is usually compatible with only a limited number of polymeric resins (Plastics) Engineering 1978). Contact of different polymers may permit reaction of incompatible substances resulting in softening, hardening, cracking, marring, and fogging. Outgassing substances also may be a source of physical or chemical incompatibility. Fogging of glazing has occurred from outgassing of improperly cured silicone sealant (Skoda and Masters 1977) and absorber coating (U.S. Department of Housing and Urban Development 1978).

Highest collector temperatures can and often do occur during system installation (Brooks et al 1978) because collector plates are exposed to the sun prior to movement of heat transfer fluid through them. This high temperature can cause thermal damage to glazing, outgassing from other materials, and buckling of the absorber plate. Keeping the collectors covered prior to system operation will reduce the probability of damage to the glazing and other components.

Contact between absorber plate and glazing has resulted from warping of the materials (Skoda and Masters 1977). Contact with the hot absorber plate may cause thermal degradation of the glazing, which results in loss of solar energy transmission. Contact may also cause the absorber coating to discolor or crack, resulting in lower solar energy absorption.

Glass Breakage

The principal problem of using glass as a glazing material is breakage, which can occur from both mechanical and thermal stress. To reduce chance of breakage from thermal stress, the following procedures are suggested: use of tempered rather than nontempered glass; use of glass with smooth edges rather than with edges that are not treated after cutting, since the latter have rough spots from which cracks may propagate; and allowing adequate means for thermal expansion at stagnation temperatures (Cash 1978).

With an evacuated tube collector, the violent fracture of glass collector tubes under stagnation conditions is the primary problem (Nichols 1978). Protective glasses and gloves should be worn when installing collector tubes.

Disposal of Plastics

Environmental degradation from plastics disposal may occur as a consequence of human management or mismanagement, rather than from inherent properties of plastics (Flintoff 1974). Plastics constitute 1 to 3% of municipal waste collected in the U.S. (Engdahl 1973). As a component of solid waste, plastics are disposed of in open dumps, in sanitary landfills, by incineration, or by recycling.

About half of the hydrogen chloride produced from incinerations is due to combustion of plastics. Other decomposition products may result from halogen and phosphorus fire retardants. However, no appreciable amounts of these or other highly toxic gases have been detected in the effluents from municipal incinerators even when large amounts of plastics were disposed of (Engdahl 1973).

In the early 1970's, polytetrafluoroethylene was the only plastic which was recycled in quantities significant compared to production (Arkles 1973). Other thermoplastics are suitable for recycling (Flintoff 1974), but there is little potential for recycling of thermosets.

Toxicity

Toxic effects may occur through ingestion of materials, exposure to outgassing products, and exposure to gases during fires.

Probability of ingestion of glazing is extremely low. Therefore, glazing itself is not considered a toxic hazard.

Considerable outgassing from plastics may occur below reported decomposition temperatures as shown by experiments in which weight loss of the plastic is determined at various temperatures (Table 4-15). The rate of outgassing may be highly dependent on exact chemical composition, as has been shown for chlorinated polyvinyl chloride (Table 4-16). Outgassing products of plastics include many of the compounds given off under pyrolysis conditions, some of which are highly toxic (see Fire Properties Section which follows).

Most glazing materials are exposed to the outside atmosphere, and human exposure to outgassing products is not likely to be significant. However, outgassing may occur at low temperatures over long periods of time. Certain designs such as some passive systems and active systems with air as a heat transfer fluid may allow gases from the glazing material to pass directly into living areas. Such designs should not use plastic glazing materials without adequate ventilation to assure that outgassing products do not lead to health problems.

Table 4-15. Outgassing weight loss and decomposition temperature of plastics[a]

PLASTIC	TEMPERATURE AT 3% WEIGHT LOSS[b] (°F)	POLYMER DECOMPOSITION TEMPERATURE (°F)
	Inert Atmosphere	
Fluorinated Ethylene Propylene	860	870
Nylon 66	680	750
Polymethylmethacrylate	450	470
Polytetrafluoroethylene	950	980
Polyvinyl Chloride	450	460
Polyvinyl Fluoride	480	480
	Oxygen Atmosphere	
Fluorinated Ethylene Propylene	880	910
Nylon 66	680	790
Polymethylmethacrylate	500	520
Polytetrafluoroethylene	980	990
Polyvinyl Chloride	510	540
Polyvinyl Fluoride	520	530

[a] Data from Arnold, C., Jr. and R. Trujillo. 1978. Composition stability and degradation products of selected materials for solar heating and cooling. SAND 78-0681. Sandia Laboratories, Albuquerque, NM.

[b] Determined by thermogravimetric analysis.

Table 4-16. Outgassing weight loss of chlorinated polyvinyl chloride[a]

CHLORINE CONTENT OF POLYVINYL CHLORIDE	TEMPERATURE AT 5% WEIGHT LOSS[b] (°F)	
	Nitrogen Atmosphere	Air Atmosphere
64%	585	566
67%	545	558
70%	612	610
72%	630	620
75%	625	617

[a] Data from Liebman, S. A., J. F. Reuwer, Jr., K. A. Gollatz, and C. D. Nauman. 1971. Thermal decomposition of poly(vinylchloride) and chlorinated poly(vinyl chloride). I. ESR and TGA studies. Journal of Polymer Science: Part A-1, 9: 1823-1833.

[b] Determined by thermogravimetric analysis.

Fire Properties

The fire properties of a plastic are dependent on its formulation, additives, dimensions, and shape. The specific properties of importance for plastics are discussed below.

Flash fire propensity data are presented in Table 4-17. Time to flash fire is an excellent indication of the speed with which flash-fire conditions develop in a real-life situation. Height of the flash fire is an indication of the strength of the fire. However, the data do not give a completely predictable indication of performance. In a full-scale fire, thickness of material, area of exposed surface, and tendency to form a surface char will be important.

Smoke emission data are presented in Table 4-18. There may be considerable difference in smoke evolution depending on whether material is smoldering or flaming.

Data concerning lethal toxicity of gases emitted from plastics under pyrolysis conditions are presented in Table 4-19. There are considerable differences in toxicity of gases from different samples of the same material as indicated by the standard deviations that are given.

Products of combustion and pyrolysis of plastics are presented in Table 4-20. Some of these products are highly toxic, as suggested by OSHA maximum allowable exposure (Table 4-21). Since plastics can produce toxic combustion and pyrolysis products, they may pose hazards during fires when they are used for glazing in or adjacent to living areas; when used outside away from living areas, they present fewer hazards. Also, many of the pyrolysis products may also be outgassing products at lower temperatures, emphasizing the need for adequate ventilation during normal operation.

The following paragraphs discuss the general fire behavior of thermoplastics and thermosets and give detailed information on the fire properties of a number of plastics (compiled from Committee on Fire Aspects of Polymeric Materials 1979).

The chemical structures of plastics greatly affect their fire properties. Thermosets, which have crosslinking between polymer chains, differ greatly from thermoplastics, which do not have cross linking. The degree and strength of the crosslinking influence the fire properties.

Upon heating, thermoplastics soften. They may soften so much when exposed to the high heat of the fire environment that they will melt and flow under their own weight. The chemical structure, presence of contaminants or additives, length of polymer chains, and temperature of the environment will determine the extent to which a specific thermoplastic will melt, drip, run, and eventually burn.

Table 4-17. Flash fire propensity of plastics[a]

PLASTIC	TIME TO FLASH FIRE (seconds)	HEIGHT OF FLAME (inches)
Acrylonitrile-Butadiene-Styrene		
Type 1	127	7
Type 2	189	7
Nylon 6	55	26
Nylon 66	95	26
Nylon 610	77	22
Polycarbonate		
Type 1	97	6
Type 2	>300	-
Polyethylene		
Type 1	115	26
Type 2	118	26
Chlorinated	110	6
Polymethylmethacrylate	61	26
Polysulfone		
Type 1 (Aryl)	>300	-
Type 2 (Aryl)	>300	-
Type 3 (Ether)	>300	-
Polyvinyl Chloride		
Type 1	>300	-
Type 2	>300	-
Type 3	>300	-
Chlorinated	>300	-
Hardwoods	28-34	15-26
Softwoods	25-33	22-26

[a] Data from Hilado, C. J. and H. J. Cumming. 1977. Screen materials for flash-fire propensity. Modern Plastics, 54(11): 56-59.

Table 4-18. Relative smoke emission from plastics[a]

PLASTIC	MAXIMUM SMOKE DENSITY (specific optical density, unitless)	
	Smoldering	Flaming
Acrylic		
FR UV-ABS	380 to 480	480
HR UV-ABS	195	90
HR UV-Trans	190 to 200	140
Polyethylene	470	150
Polytetrafluoroethylene	0	55
Polyvinyl Chloride		
Filled	490	530
Unfilled 0.0125 in.	272	525
Unfilled 0.025 in.	470	535
Hardwood (Red Oak)	395	75
Softwood (Douglas Fir)	380	155

[a] Data from Gaskill, J. R. and C. R. Veith. 1968. Smoke opacity from certain wood and plastic. Fire Technology.

Table 4-19. Toxicity of pyrolysis gases from plastics[a]

PLASTIC	TIME TO DEATH OF MICE[b] (minutes)	NUMBER OF SAMPLES
Acrylonitrile-Butadiene-Styrene	17.13 ± 2.45	3
Nylon	14.36 ± 1.71	3
Polycarbonate	20.40 ± 3.77	3
Polyethylene	17.31 ± 3.73	5
Chlorinated	26.08 ± 1.80	2
Polymethylmethacrylate	15.58	1
Polyvinyl Chloride	16.60 ± 0.33	2
Chlorinated	22.25 ± 0.69	2
Polyvinyl Fluoride	20.50	1
Polyvinylidene Fluoride	15.86	1
Wood	14.03 ± 1.48	12

[a] Data from Hilado, C. J., H. J. Cumming, and C. J. Casey. 1978. Relative toxicity of materials in fire situations. Modern Plastics, April 1978: 92-96.

[b] Values given are mean ± standard deviation among samples.

Table 4-20. Combustion and pyrolysis products from plastics[a]

PLASTIC	COMBUSTION PRODUCTS	PYROLYSIS PRODUCTS
Fluorinated Ethylene Propylene	Carbon Monoxide Carbon Dioxide Silicone Tetrafluoride Carbonyl Fluoride	Tetrafluoroethylene Hexafluoropropylene
Nylon 66	Carbon Monoxide Carbon Dioxide Methane Hydrogen Cyanide Ammonia Ethylene Acetylene	Carbon Dioxide Water Ammonia Hydrogen Cyanide Organic Nitriles Cyclic Ketones Esters Hydrocarbons
Polymethylmethacrylate	Methylmethacrylate Carbon Monoxide Carbon Dioxide Ethylene Hydrogen	Methylmethacrylate Benzene Water
Polytetrafluoroethylene	Carbon Monoxide Carbon Dioxide Difluoroformaldehyde Tetrafluoroethylene Silicon Tetrafluoride Formed via Reaction With Glass	Tetrafluoroethylene Carbon Tetrafluoride
Polyvinyl Chloride	Hydrogen Chloride Carbon Monoxide Carbon Dioxide Vinyl Chloride Benzene Toluene Methane Ethane Methyl Chloride Carbonyl Sulfide Sulfur Dioxide Butane Pentane Butene	Hydrogen Chloride Vinyl Chloride Benzene Toluene Saturated and Unsaturated Aliphatic and Aromatic Compounds

(continued)

Table 4-20. continued

PLASTIC	COMBUSTION PRODUCTS	PYROLYSIS PRODUCTS
Polyvinyl Fluoride	Carbon Dioxide Benzene Hydrogen Fluoride Fluorobenzene Xylene Vinyl Fluoride	Hydrogen Fluoride Butadiene Allyl Fluoride Benzene Toluene Naphthalene Vinyl Fluoride

[a] Data from Arnold, C., Jr. and R. Trujillo. 1978. Composition stability and degradation products of selected materials for solar heating and cooling. SAND 78-0681. Sandia Laboratories, Albuquerque, NM; and Adams, S. I. 1977. Analysis of combustion gases during testing with the NBS smoke chamber. Journal of Combustion Toxicology, 4: 360-366.

Table 4-21. OSHA exposure limits for selected gaseous combustion and pyrolysis products from plastics[a]

PRODUCT	MAXIMUM ALLOWABLE EXPOSURE[b] (ppm)
Ammonia	50
Benzene	10
Butadiene	1000
Carbon Dioxide	5000
Carbon Monoxide	50
Hydrogen Chloride	5
Hydrogen Cyanide	10
Hydrogen Fluoride	3
Methyl Chloride	100
Pentane	1000
Sulfur Dioxide	5
Toluene	200
Vinyl Chloride	1
Xylene	100

[a] Data from Occupational Safety and Health Administration. 1977. Code of Federal Regulations, Title 29, Chapter XVII. U.S. Government Printing Office, Washington, DC.

[b] OSHA has established maximum tolerable exposure limits (8-hour weighted average) for more than 400 gases. The least toxic of these gases is carbon dioxide with a limit of 5000 ppm. The most toxic is nickel carbonyl with a limit of 0.001 ppm.

Thermosets do not soften upon heating. The crosslinking between polymer chains remains intact even at relatively high temperatures. The extent to which thermosets are flammable depends on the emission of combustible gases which serve to fuel a continuous fire. Little flammable fuel is generated by many thermosets exposed to flame. A surface char is produced which insulates and protects the subsurface portion of the plastic from heat and flame. This char is destroyed only at extremely high temperature. Because of the properties of this surface char, the plastics are inherently fire resistant, even without the addition of fillers or additives.

Precautions provided by manufacturers about their products contain valuable information and should be heeded, as illustrated by the following recommendation (Cyro Industries 1978):

> (Acrylic) sheet is produced from an acrylic molding compound which is a combustible thermoplastic. Precautions used to protect wood and other combustibles from flames and high heat sources should also be observed with this material. Acrylic materials usually burn rapidly to completion if not extinguished. The products of combustion, if sufficient air is present, are carbon dioxide and water. However, in many fires sufficient air will not be available and toxic carbon monoxide will be formed, as it will from other common combustible materials. We urge good judgment in the use of this versatile material and recommend that building codes be followed carefully to assure it has been used properly.

Acrylic - Polymethyl methacrylate (PMMA) readily ignites. Combustible volatiles are generated by pyrolysis when heat is applied to the plastic by flame or other source. The volatiles contain methyl methacrylate monomers plus some molecules of higher molecular weight. They burn in the gas phase. The heat generated by their combustion stimulates further pyrolysis and subsequent combustion. PMMA produces less smoke than polymers composed only of hydrogen and carbon.

Fire retardants for PMMA include halogen- and antimony- containing compounds. They reduce both the ease of ignition and burning rates. However, the use of retardants can reduce the good aging and transparency qualities of PMMA.

Fluorinated Ethylene Propylene and Polytetrafluoroethylene - These fluorine-containing compounds do not support combustion. However, they will burn under suitable conditions. At high temperatures existing during intense fires, polytetrafluoroethylene can break down to its monomer which can then oxidize to carbonyl fluoride, a hazardous gas, under certain conditions.

Nylon - Nylon tends to drip as it burns, exhibiting a "self extinguishing" characteristic by allowing the burning portion to separate from the nonburning portion. Glass fiber and mineral fillers used in nylon composites to enhance engineering properties prevent or reduce this dripping. Thus, such composites may burn more readily than unfilled nylon.

Halogen-and phosphorus-containing compounds, iron oxides, and hydrated alumina are used as fire retardants in nylon.

Polybutylene and Polyethylene - These hydrocarbons are easily ignited, burn with a smoky flame, and melt as they burn, much like paraffin wax.

Halogen-containing compounds and antimony oxide are used as fire retardants. Increased chlorine content of compositions results in decreased flammability. Compositions with chlorine content of 25 to 40 percent by weight may extinguish under some fire conditions. However, in a fully developed fire, all fire retardant compositions are likely to burn.

Polycarbonate - Polycarbonates char to a limited extent during pyrolysis and combustion. They may extinguish under some fire conditions. Incorporation of halogens into the polymer structure during synthesis or addition of halogen-containing compounds with or without antimony oxide after synthesis can further increase the fire resistance of polycarbonates.

Polyester - Polyester burns with a smoky flame. The smoke arises from the combustion of styrene, a pyrolysis product of polyester. Smoke is only moderately reduced by the use of fire retardants.

Alumina hydrate is an inorganic filler which reduces fire propensity. It has the advantages of providing structural reinforcement to the plastic, being low in cost, and lowering generation of smoke. It does not produce corrosive gases during fires as halogen-containing fire retardants may produce. However, alumina hydrate cannot fire retard polyester to the same degree that the halogen fire retardants can.

Organic fire retardants include phosphorous compounds, chlorinated waxes, organic antimony compounds, and chlorinated biphenyls. The latter, however, are carcinogens and should not be used. The good thermal stability, resistance to leaching, and fire retardant characteristics of chlorocarbons has indicated their potential for use as fire retardants in polyester.

Halogens can be incorporated into the polymer chain by the use of proper compounds in the synthesis of polyester. Commonly used compounds include chlorendic acid, tetrachlorophthalic acid, and tetrabromophthalic acid. The latter allows excellent fire retardant characteristics with a bromine content of 15 percent by weight.

Crosslinking agents provide another means of introducing fire retardants into polyester. Specific phosphorus-and halogen-containing compounds can be used, but their high cost necessitates that they be used in combination with other fire retardants and only when special properties are required.

Polyethylene Terephthalate - Melting and dripping are common with this thermoplastic. Little char is formed. Halogen-containing compounds with or without metal oxide synergists are used as fire retardants. The fire retarded plastic resists ignition in a low heat environment, but readily burns in a fully developed fire.

Polyimides - Aromatic polyimides yield high char during pyrolysis, with up to 60 percent of the initial weight being converted to char. They have low flammability and low smoke production.

Polysulfones - Aromatic polysulfones char when exposed to flame. They are quite fire resistant even without the addition of fire retardants.

Polyvinyl Chloride - The high chlorine content of polyvinyl chloride makes this plastic by itself very fire resistant. Hydrogen chloride, a corrosive gas, is emitted when the plastic is heated or exposed to flame and acts to quench combustion.

Combinations of polyvinyl chloride with phthalate, sebacate, and adipate esters and other plasticizers have fire properties different from polyvinyl chloride itself. They may require the addition of fire retardants. Some compounds containing chlorine or phosphorus serve as plasticizers as well as fire retardants. These include tricresyl phosphate, cresyl diphenyl phosphate, 2-ehtylhexyl diphenyl phosphate, and chlorinated paraffins. Antimony oxide can be added as a synergist to these fire retardants.

Polyvinyl Fluoride - Polyvinyl fluoride is more flammable than polyvinyl chloride, despite their similar chemical structures. Hydrogen fluoride, a corrosive gas, is generated at temperatures exceeding 480°F, but is does not quench combustion as effectively as hydrogen chloride. Combustible volatiles are generated at higher temperatures and serve as fuel for a fire.

Polyvinylidene Fluoride - This fluorine-containing plastic has less thermal stability than polytetrafluoroethylene but has greater thermal stability than polyvinyl fluoride. Hydrogen fluoride is generated at 800°F. Char of up to 40 percent of the initial weight is formed during pyrolysis at that temperature.

REFERENCES

Adams, S. I. 1977. Analysis of combustion gases during testing with the NBS smoke chamber. Journal of Combustion Toxicology, 4: 360-366.

Advanced Energy Programs. 1977. Engineering data package, TC-100 vacuum tube solar collector. General Electric Company, Philadelphia, PA.

Agranoff, J. (ed.) 1978. Modern Plastics Encyclopedia, 55(10A). McGraw-Hill Inc., New York, NY.

Agranoff, J. (ed.) 1979. Modern Plastics Encyclopedia, 56(10A). McGraw-Hill Inc., New York, NY.

Arkles, B. 1973. Recycling poly(tetrafluoroethylene). In J. Guillet (ed.) Polymers and Ecological Problems. Plenum Press, New York, NY.

Arnold, C., Jr., and R. Trujillo. 1978. Composition stability and degradation products of selected materials for solar heating and cooling. SAND 78-0681. Sandia Laboratories, Albuquerque, NM.

Blaga, A. 1978. Use of plastics in solar energy applications. Solar Energy, 21: 331-338.

Brooks, J., J. S. Rickard, J. Easterly, and T. Statt. 1978. Solar system start-up and operational concerns. In Preconference Proceedings - Solar Heating and Cooling Systems Operational Results. U.S. Department of Energy. SERI/TP-49-063 preliminary.

Cash, M. 1978. Hardware problems encountered in solar heating and cooling systems. DOE/NASA TM-78172. Technical Memorandum. (Available from NTIS, Springfield, VA.)

Chiou, J. P. 1977. On the study of applications of solar thermal energy for mobile homes. Solar Energy, 19: 449-466.

Committee on Fire Safety Aspects of Polymeric Materials. 1979. Fire safety aspects of polymeric materials. Volume 5. Elements of polymer fire safety and guide to the designer. Publication NMAB 318-5. National Academy of Sciences, Washington, DC.

Copper Development Association, Inc. 1978. Solar energy systems. Copper Development Association, Inc., New York, NY.

Cyro Industries. 1978. Acrylite SDP acrylic double skinned sheet. Bulletin MD 2B. Cyro Industries, Wayne, NJ.

Cyro Industries. 1977. SDP polycarbonate double skinned sheet. Bulletin MD 3A. Wayne, NJ.

DuPont. 1975. DuPont Tedlar PVF Film. Bulletin TD-31. DuPont de Nemours and Co., Wilmington, DE.

Engdahl, R. B., H. H. Krause, and P. D. Miller. 1973. Effluents from the municipal incineration of plastics. In J. Guillet (ed.) Polymers and ecological problems. Plenum Press, New York, NY.

Flintoff, F. L. D. 1974. The disposal of solid wastes. In I. J. Staudinger (ed.) Plastics and the Environment. Hutchinson and Co. Ltd., London.

Gaskill, J. R. and C. R. Veith. 1968. Smoke opacity from certain woods and plastic. Fire Technology.

Hilado, C. J. and H. J. Cumming. 1977. Screen materials for flash-fire propensity. Modern Plastics, 54(11): 56-59.

Hilado, C. J., H. J. Cumming, and C. J. Casey. 1978. Relative toxicity of materials in fire situations. Modern Plastics, April 1978: 92-96.

Knudtson, P. 1978. Glazing materials: some alternatives. New Mexico Solar Energy Association Bulletin, 3(1): 15-18.

Liebman, S. A., J. F. Reuwer, Jr., K. A. Gollatz, and C. D. Nauman. 1971. Thermal decomposition of poly(vinylchloride) and chlorinated poly(vinyl chloride). I. ESR and TGA studies. Journal of Polymer Science: Part A-1, 9: 1823-1833.

Montgomery, R. H. 1978. The Solar Decision Book; Your Guide to Making a Sound Investment. Dow Corning, Midland, MI.

Nichols, R. L. 1978. Owens Illinois liquid solar collector materials. Technical support package. Brief No. MFS-23926. National Aeronautics and Space Administration. Marshall Space Flight Center, AL.

Occupational Safety and Health Administration. 1977. Code of Federal Regulations, Title 29, Chapter XVII. U.S. Government Printing Office, Washington, DC.

Pennwalt Corporation. 1977. Kynar extruded film, technical data. TD-18. Pennwalt Corporation, Philadelphia, PA.

Plastics Engineering. 1978. Additives for plastics-plasticizers. Plastics Engineering, 33(1): 32-38.

Plastic Products and Resins Department. Teflon FEP for solar collectors. Advertising Bulletin E-09700. DuPont de Nemours and Co., Wilmington, DE.

Rainhart, L.G. and W. P. Schimmel, Jr. 1975. Effect of Outdoor Aging on Acrylic Sheet. Solar Energy, 17: 259-264.

Skoda, L. F. and L. W. Masters. 1977. Solar energy systems - survey of materials performance. National Bureau of Standards. NBSIR 77-1314.

Solar Age Magazine. 1979. Solar Products Specifications Guide. Harrisville, NH.

Solar Components Division. Sun-Lite Premium II. Advertising bulletin. Kalwall Corporation, Manchester, NH.

Sparkes, H. R. and K. Raman. 1978. Lessons learned on solar system design problems from the HUD Solar Residential Demonstration Program. In Conference Proceedings - Solar Heating and Cooling Systems Operational Results. U.S. Department of Energy. SERI/TP-49-063.

Swedcast Corporation. 1977. Solar collector panels. Technical Bulletin 139. Swedcast Corporation, Florence, KY.

3M Company. 1978. 7410 Flexigard Protective Film; Flexigard 7410 Protective Film, Solar Collectors - Storm Windows - Greenhouses. Advertising bulletins. 3M Company, St. Paul, MN.

U.S. Department of Housing and Urban Development. 1978. Building the solar home. HUD-PDR-296-1. (Available from U.S. Government Printing Office, Washington, DC.)

Westlake Plastics Company. Kynar film. Advertising bulletin. Westlake Plastics Company, Lenni, PA.

GLAZING WORKSHEET

EXPOSURE CONDITIONS	Materials in contact with glazing during normal operation: Materials in contact with glazing during abnormal operation: Linear expansion coefficients of associated materials: Temperature of glazing at stagnation: Exposure to UV radiation: Exposure to humidity: Exposure to outdoor atmosphere: Exposure to outgassing from other materials:	
FUNCTIONAL PROPERTIES	SOLAR TRANSMITTANCE	The higher the %, the more desirable. 100% is optimal. See Tables 4-2 through 4-8. Benchmark: glass has solar transmittance of 84 to 91%.
	LONGWAVE TRANSMITTANCE	The lower the %, the more desirable. 0% is optimal. See Tables 4-2 through 4-8. Benchmark: glass has longwave transmittance of 2%.
ENVIRONMENTAL AND SAFETY CONSIDERATIONS	UPPER TEMPERATURE LIMIT	A limit above the temperature reached at stagnation is desirable. See Tables 4-2 through 4-8.
	WEATHERING CHARACTERISTICS	The higher the resistance to degradation by UV radiation, temperature, humidity, and other weathering agents, the more desirable. See Tables 4-2 through 4-8, and 4-14. Benchmark: glass has excellent weathering resistance.
	LINEAR EXPANSION COEFFICIENT	The closer the coefficient is to the coefficients of other system materials, the more desirable. See Tables 4-2 through 4-8, and 4-11. Benchmark: copper has a coefficient of 9.3×10^{-6}/°F.
	COMPATIBILITY	The lower the chemical interaction with materials contacted during normal and abnormal operation, the more desirable. See Tables 4-12 and 4-13.
	OUTGASSING	The lower the amount and rate of outgassing, the more desirable. See Table 4-15.
	FIRE PROPENSITY	The lower the capability to catch on fire and burn, the more desirable. See Table 4-17. Benchmark: with the Hilado-Cumming screening test, woods ignite in 25 to 34 seconds and flame reaches a height of 15 to 26 inches. These benchmarks will be different for other fire tests.
	FIRE TOXICITY	The lower the toxicity (the higher LC_{50}s or allowable exposure limits) of combustion and pyrolysis gases, the more desirable. See Tables 4-20 and 4-21.
	SMOKE EMISSION	The lower the smoke emission, the more desirable. See Table 4-18. Benchmark: with the Gaskill-Veith test, smoldering hardwood has a maximum smoke density of 395 and flaming hardwood has a maximum smoke density of 76. These benchmarks will be different for other fire tests.

GLAZING WORKSHEET

	PRODUCT GENERIC TYPE	PRODUCT GENERIC TYPE	PRODUCT GENERIC TYPE	PRODUCT GENERIC TYPE
SOLAR TRANSMITTANCE				
LONGWAVE TRANSMITTANCE				
UPPER TEMPERATURE LIMIT				
WEATHERING CHARACTERISTICS				
LINEAR EXPANSION COEFFICIENT				
COMPATIBILITY				
OUTGASSING				
FIRE PROPENSITY				
FIRE TOXICITY				
SMOKE EMISSION				

Solar Products Specifications Guide

SOLATEX^R SOLAR GLASS

AFG Industries, Inc.
1400 Lincoln St.
Kingsport, TN 37662

Ronald Tiller (800) 251-0441, (615) 245-0211

TECHNICAL SPECIFICATIONS

Material and type: Rolled, tempered glass with 0.04% iron-oxide content

Transmittance: 89.5 to 89.8%

Index of refraction: ≈ 1.52

Weight: 1/8 in, 1.6 lb/ft^2
5/32 in, 2.0 lb/ft^2
3/16 in, 2.4 lb/ft^2

Tensile strength: 6400 psi

Impact strength: 5 ft-lb/in

Coefficient of thermal expansion: 47×10^{-7} to $51 \times 10^{-7}/°F$ between 32 and 572°F

Flammability: Noncombustible

Surface weathering: Excellent

Maximum continuous service temperature: 400°F

Thermal degradation: None

Ultraviolet degradation: None

Optical clarity: Translucent

Standard sizes available:
1/8 in: 34 x 76 in
5/32 in: 34 x 76, 96 in
3/16 in: 34 x 76, 96 in
46 x 76, 96 in

PRODUCT DESCRIPTION

A low iron solar energy glass in the medium price range. The iron content is about 0.04% Iron Oxide. May be used in active or passive systems. Material contains a light surface pattern making it translucent rather than transparent.

Features: Solar transmittance 89.5%

Options: Should be use fully tempered.

Installation Requirements: Low coefficient of expansion promotes easy and permanent sealing.

Maintenance Requirements: None.

Guarantee/Warranty: Limited warranties available.

Suggested List Price: Less expensive than more efficient Sunadex solar glass.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

HELIOLITE^R

C-E Glass, Div. of Combustion Engineering Inc.
825 Hylton Rd.
Pennsauken, NJ 08110

R. H. McCurdy (609) 662-0400

TECHNICAL SPECIFICATIONS

Material and type: Low iron glass, 0.03% iron oxide content, patterned, tempered

Transmittance: 1/8 in = 90.1%; 5/32 in = 89.6%; 3/16 in = 89.0%

Index of refraction: 1.5

Weight: 1/8 in = 1.6 lb/ft^2; 5/32 in = 2.0 lb/ft^2; 3/16 in = 2.5 lb/ft^2

Tensile strength: 20,000 psi

Impact strength: 4 times stronger than annealed glass

Coefficient of thermal expansion: 90 x 10^{-7} per °C (@ 0 to 300°C)

Flammability: None

Surface weathering characteristics: Excellent

Maximum continuous service temperature: 500°F

Thermal degradation: None

Ultraviolet degradation: None

Optical clarity: Translucent

Standard sizes available: 34 x 76/84/92/96 and 46 x 76/84/92/96 in

Limitations: Cannot be used for vision areas in passive applications

PRODUCT DESCRIPTION

A low iron pattern glass, fully tempered, available in 3 thicknesses and 8 standard sizes, as well as non-standard custom sizes.

Features: High transmissivity, high obscurity, low specular reflectance.

Options: Also available as an insulated unit under trade name Heliopane^R. Constructed with Heliolite^R and dual seal sealants, including silicone.

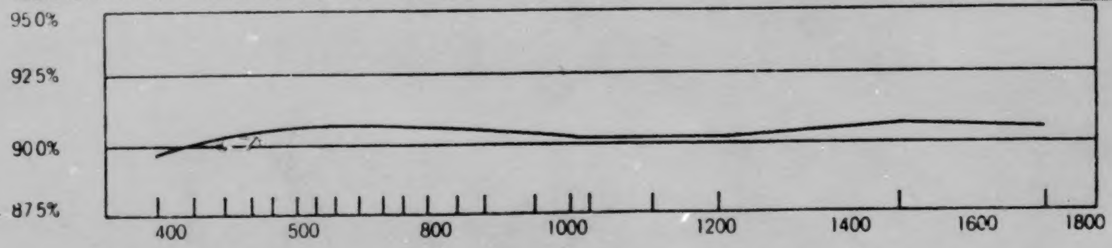
Installation Requirements: None.

Maintenance Requirements: None.

Guarantee/Warranty: Conforms to Federal Specification DDG-451D.

Suggested List Price: Prices vary widely, consult manufacturer.

TRANSMITTANCE CURVES FOR 1/8" HELIOLITE



(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

SOLAKLEER^{TM} CLEAR SOLAR GLASS

General Glass International Corp.
270 North Ave.
New Rochelle, NY 10801

David Balik (914) 235-5900

TECHNICAL SPECIFICATIONS

Material and type: Clear solar glass, 0.057% iron content

Transmittance: 91.3% for 1 mm thickness, see graph and table

Index of refraction: 1.52

Weight: See table

Tensile strength: Approx 13700 psi

Impact strength: Hardness factor, 3.5 to 4.0 kg

Coefficient of thermal expansion: Linear expansion, 86.6 x 10^7 (0 to 300°C)

Flammability: Nonflammable

Surface weathering characteristics: Excellent

Maximum continuous service temperature: Approx 600°F

Thermal degradation: None

Ultraviolet degradation: None

Optical clarity: Transparent, optically flat

Standard sizes available: 34 x 76 in, 46 x 76 in, 34 x 96 in, custom sizes available

Limitations: Maximum size, 84 x 96 in

PRODUCT DESCRIPTION

A clear low iron flat glass with 91.3% TSET (1 mm) and optical flatness. Nearly color free. Available cut to size for specific high technology sunlight focusing applications and standard collector sizes. Highly suitable for active, and especially passive systems.

Features: Clear, and very thin. For current and future applications.

Options: Six thicknesses ranging from 0.040 in. (1 mm) up to 0.203 in. (5.5 mm). Tempering available on request.

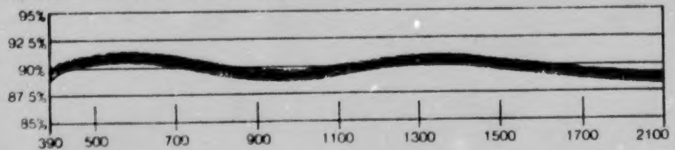
Installation Requirements: Consult ANSIA 134-1-1970 or AAMA Spec. 302-7-1971.

Maintenance Requirements: None.

Guarantee/Warranty: Limited warranty.

Suggested List Price: Prices vary widely, consult manufacturer.

Spectral Transmittance (1 0 mm SOLAKLEER)



The TSET specifications shown were measured in the range of 390-1722 nanometers (millimicrons) by Beckman Spectrophotometer equipment in accordance with testing procedure ASTM E 424-71.

Physical Properties

Nominal Thickness	Maximum Size	Weight per Sq. Ft.	TSET*
1mm (038"- 042")	Cut to your specs	507	91 3%
2 5mm (030")	60" x 84"	1 183	90 5%
1/8"	84" x 96"	1 625	90 1%
5/32"	84" x 96"	1 976	89 5%
3/16"	84" x 96"	2 509	88 8%
13/64"	84" x 96"	2 762	88 5%

*Data provided by Battelle Pacific Northwest. Laboratories, Richland, Washington

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

FILON^R SOLAR PANELS 546 & 556

Filon Div. of Vistron Corp.
12333 Van Ness Ave.
Hawthorne, CA 90250

Don Graves (213) 757-5141

TECHNICAL SPECIFICATIONS

Material and type: Fiberglass-reinforced polyester, acrylated and weather-surfaced with proprietary gelcoat

Transmittance: 94% light (ASTM D-1494); 85.3 to 86.6% solar energy (ASTM E-424 Method A)

Index of refraction: 1.540

Weight: 4 oz/ft^2 and 5 oz/ft^2

Tensile strength: 14,500 (ASTM D-638)

Impact strength: 2.4 - 5.3 ft-lb/in width (IZOD, ASTM D-256)

Coefficient of thermal expansion: 2.3×10^{-5} in/in/°F (ASTM D-696)

Flammability: Less than 2 in/min (ASTM D-635)

Surface weathering characteristics: Resists UV degradation and most erosive and corrosive atmospheres. Resists most acids, alkalies, hydrocarbons, alcohols, peroxides, etc

Maximum continuous service temperature: 150°F

Thermal degration: Not specified

Ultraviolet degradation: Not specified

Optical clarity: Translucent

Standard sizes available: Maximum span width for each thickness available: Maximum span: 36 in for 4 oz corrugated; 48 in for 5 oz corrugated; 24 in for flat panels

Limitations: Do not use to glaze open water collectors. Use dessicant if collector develops excessive interior moisture

PRODUCT DESCRIPTION

These acrylic-enriched polyester panels are reinforced with 25 to 27% random strand fiberglass and parallel nylon strands. Exposed side is surfaced with proprietary gelcoat.

Features: High transmissivity, low reflectance, shatter-resitant; special gelcoat surface resists degradation, erosion, and corrosive atmospheres.

Options: Stocked: two weights, 4 oz. and 5 oz. per ft^2 in flat or 2-1/2 in. corrugated panels. Lengths: 8 ft., 10 ft., 12 ft. Flat also available in rolls; 4 oz. - 100 ft. long; 5 oz. - 50 ft. long.

Installation Requirements: None specified.

Maintenance Requirements: Periodic water rinse to remove accumulated dirt.

Guarantee/Warranty: Not available at this time.

Suggested List Price: 68¢/ft^2 to \$1.38/ft^2.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

UVEX™ PLASTIC SHEET

Eastman Chemical Products, Inc., subsidiary
of Eastman Kodak Co.
Bldg. 280
Kingsport, TN 37662
Wm. J. Seaman (615) 246-2111 Ext. 2924

TECHNICAL SPECIFICATIONS

Material and type: A cellulosic, cellulose acetate butyrate

Transmittance: 90%

Index of refraction: 1.47

Weight: 0.060 in, 0.374 lb/ft^2; 0.250 in, 1.56 lb/ft^2

Tensile strength: 5700 psi

Impact strength: 0.125 in: 26 ft-lb at 73°F, 23 ft-lb at 0°F

Coefficient of thermal expansion: 1/16 in per ft per 100°F change in temp

Flammability: 1.4 in per min, ASTM D 635-74

Surface weathering characteristics: Some hazing after 3-yrs

Maximum continuous service temperature: 180°F

Thermal degradation: U.S. Testing Report No. A51274 (1/12/77), same toxicity as burning wood. Smoke density, ASTM D 2843-70: 0.060 in, 3.6; 0.150 in, 16.5; 0.250 in, 26.7

Ultraviolet degradation: Loss of gloss, reduction of impact strength

Optical clarity: Transparent

Standard sizes available: 8 x 12 ft standard; 0.060, 0.080, 0.100, 0.125, 0.150, 0.187, 0.220 or 0.250 in thick

Limitations: Do not use flat

PRODUCT DESCRIPTION

A clear, transparent cellulose acetate butyrate sheeting that has excellent forming characteristics, good greenhouse properties and 90% light transmittance.

Features: Good weathering, high impact resistance.

Options: Many standard size sheets, 8 thicknesses. Transparent colors are available.

Installation Requirements: Allow material to move 1/16 in per ft. when put in a retainer.

Maintenance Requirements: Can be washed with mild detergent and warm water.

Guarantee/Warranty: None.

Suggested List Price: 0.060 in., $ .685 to $ .885.
0.125 in., $1.36 to $1.76.
Prices are approximate, and depend on quantity and distributor location.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

"TEDLAR" PVF FILM 400SE

Du Pont Company
Polymer Products Department
Talley Bldg., Concord Plaza
Wilmington, DE 19898

R. P. deBussy (302) 772-5880

TECHNICAL SPECIFICATIONS

Material and type: Polyvinyl flouride film 4 mil thick

Transmittance: 90% of the solar spectrum

Index of refraction: 1.46 n_D (ASTM D 542)

Weight: 0.029 lb/ft^2

Tensile strength: 12,000 psi (ASTM D 882 Method A)

Impact strength: Not specified

Coefficient of thermal expansion: $2.8 \times 10^{-5}/°F$

Flammability: 0.7 in/min (ASTM D 635) Self ignition temp 730°F

Surface weathering characteristics: Excellent

Maximum continuous service temperature: 225°F continuous, up to 350°F for short periods

Thermal degradation: No thermal degradation at use temperature

Ultraviolet degradation: UV resistant

Optical clarity: Transparent

Standard sizes available: In rolls up to 100 inches in width

Shrinkage: At 266°F, approximately 2 to 3% total, length and width combined

PRODUCT DESCRIPTION

An improved form of "Tedlar" PVF film developed specifically for single or outer glazing on solar collectors.

Features: High solar transmission, excellent weatherability and toughness, lightweight.

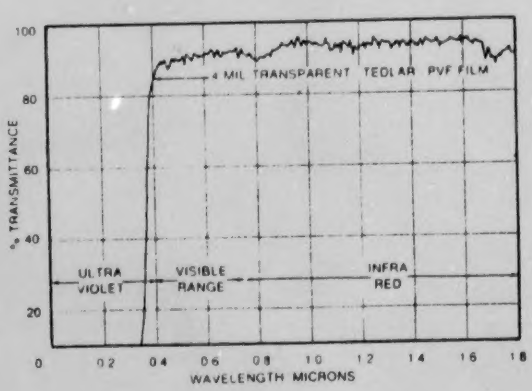
Options: Film widths slit to customer's requirements. Available in various standard roll put-ups.

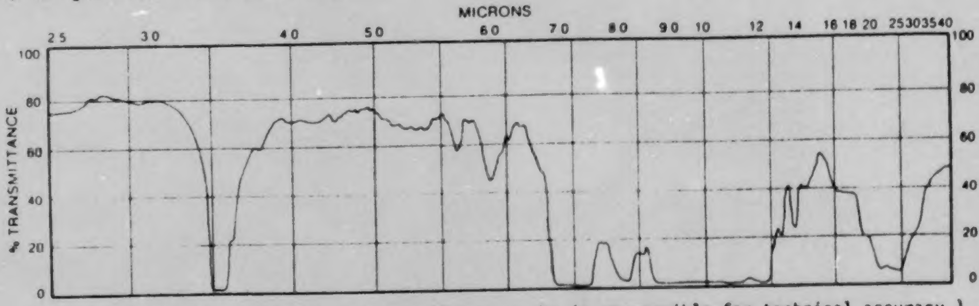
Installation Requirements: Heat shrink to obtain a taut surface.

Maintenance Requirements: None known.

Guarantee/Warranty: Not available.

Suggested List Price: 29.7¢/ft^2





(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

HELIO THERMICS COLLECTOR COVER

Helio Thermics, Inc.
1070 Orion St.
Donaldson Industrial Park
Greenville, SC 29605

Bill Haas (803) 299-1300

TECHNICAL SPECIFICATIONS

Material and type: Cross-corrugated fiberglass (FRP) top layer Tedlar coated to filter UV

Transmittance: 76% for both layers

Index of refraction: Not specified

Weight: 10 oz/sq ft (for both layers)

Tensile strength: 10,600 psi (ASTM D-638)

Impact strength: Not specified

Coefficient of thermal expansion: 2.3×10^{-5} in/in/°F (ASTM D-696)

Flammability: 0.98 in/min (ASTM D-635)

Surface weathering characteristics: Virtually impervious to erosive and corrosive atmospheres

Maximum continuous service temperature: 220°F

Thermal degradation: Heat distortion - 220°F at 264 lbs/in^2 and 319°F at 66 lbs/in^2 (ASTM D-648)

Ultraviolet degradation: Not specified

Optical clarity: Translucent

Standard sizes available: 4 ft (51-3/8 in) and lengths 8 ft, 10 ft, 12 ft, (up to 32 ft by special order) 5 oz/ft^2

PRODUCT DESCRIPTION

As the collector is built into the structure in most instances, the collector cover material replaces conventional roofing material, and consists of a cross-corrugated fiberglass (patented) attached to the rafters. It is site-built. Top layer is Tedlar coated.

Features: Replaces conventional roofing material.

Options: Top layer lengths available in 8 ft, 10 ft., 12 ft., other lengths up to 32 ft. by special order.

Installation Requirements: Complete information and diagram accompanies order.

Maintenance Requirements: None.

Guarantee/Warranty: 5-yr.

Suggested List Price: \$2.50/collector ft.^{2} includes both layers of fiberglass and all components (screws, washers, redwood strips, flashing, sealant) needed to apply. Price subject to change.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

SUN-LITE^R

Kalwall Corp.
Solar Components Div.
P.O. Box 237
Manchester, NH 03105
William Sullivan (603) 668-8186

TECHNICAL SPECIFICATIONS

Material and type: Fiberglass-reinforced polymer

Transmittance: 85 to 90% solar transmittance by ASTM E 424 Method B

Index of refraction: 1.58

Weight: Ranges from 4 to 8 oz/ft^2 depending on thickness

Tensile strength: 10,000 psi (by ASTM D638)

Impact strength: 28 ft-lb (by SPI Falling Ball Test, Method B)

Coefficient of thermal expansion: 1.36 in/in/°F x 10^{-5} (by ASTM D 696)

Flammability: Less than 2-1/2 in/min by ASTM D635

Surface weathering characteristics: Good resistance/field refinishable

Maximum continuous service temperature: 200°F

Thermal degradation: 3000 hr at 200°F = 3% transmission loss; 3000 hr at 250°F = 3%; 300 hr at 300°F = 9%

Ultraviolet degradation: 12-mo actual exposure in southern Florida = 1% transmission loss

Optical clarity: Partially transparent

Standard sizes available: Thickness - 0.025 in, 0.040 in, 0.060 in; widths 24 in, 36 in, 48 in, 49-1/2 in, 60 in, lengths 10 ft, 25 ft, 50 ft, 1500 ft

Limitations: Material should not be continuously exposed to temperatures above 200°F although short-term (1 to 2 days) exposure up to 300°F is permissable

PRODUCT DESCRIPTION

Sun-Lite^R is a fiberglass-reinforced polymer glazing material specifically developed for solar collector cover applications. This partially translucent material offers 85 to 90 percent solar transmittance and high-impact strength and durability.

Features: Kalwall Weatherable Surface applied at factory for additional surface erosion protection.

Options: None

Installation Requirements: Typical unsupported span of 24 in.; minimum distance to mechanical fastener of 3/4 in.

Maintenance Requirements: Cleaning and field-applied weatherable surface coating at 10 yr. intervals suggested.

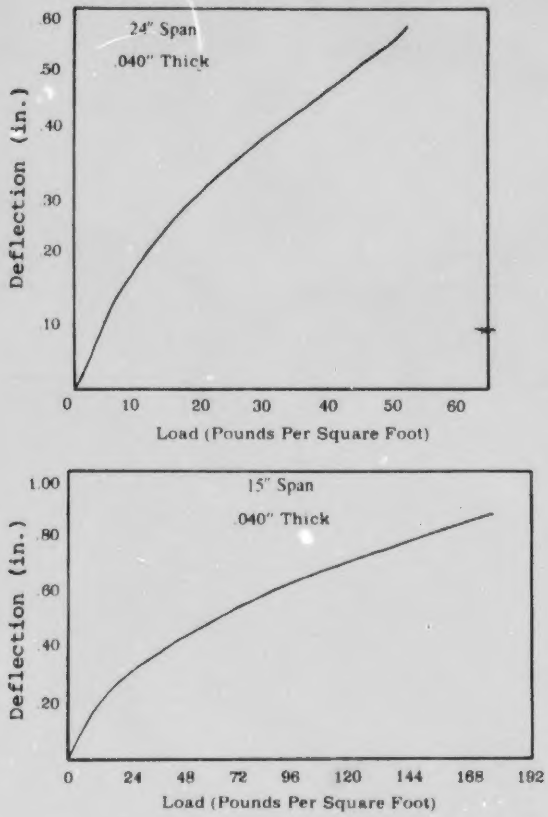
Guarantee/Warranty: 30 days materials and workmanship.

Suggested List Price: \$ .64 to \$1.29/ft^2.

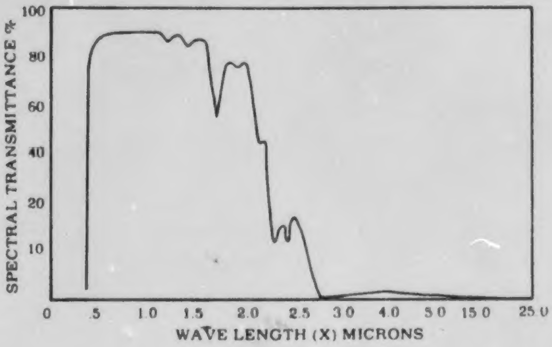
(This information is provided by the manufacturer, who is responsible for technical accuracy.)

SUN-LITE^R

TRANSVERSE LOAD DEFLECTION



SPECTRAL TRANSMITTANCE



SOLAR TRANSMITTANCE VS. ANGLE OF INCIDENCE

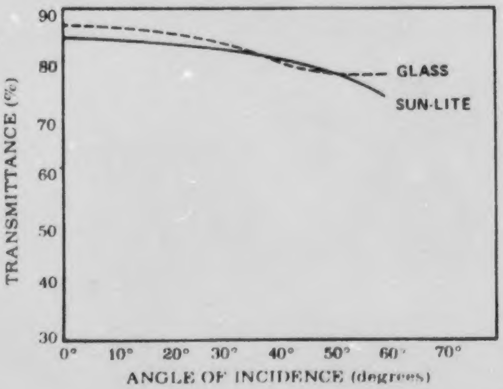
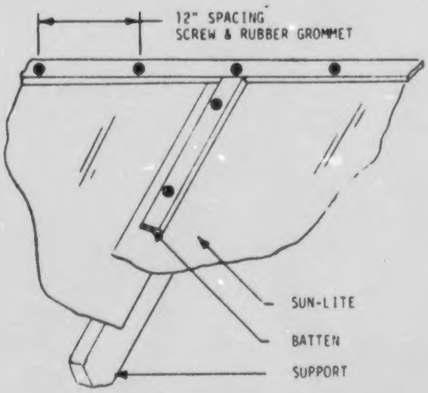
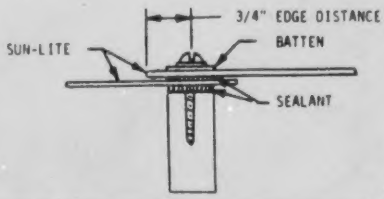


TABLE 1

Sun-Lite Thickness	Suggested Span	Maximum Span
.025	24"	30"
.040	24"	30"
.060	30"	36"


12" SPACING
SCREW & RUBBER GROMMET
SUN-LITE
BATTEN
SUPPORT


3/4" EDGE DISTANCE
SUN-LITE
BATTEN
SEALANT

Solar Products Specifications Guide

SUNWALL^{R}

Kalwall Corp., Solar Components Div.
P.O. Box 237
Manchester, NH 03105

Tom Child (603) 668-8186

TECHNICAL SPECIFICATIONS

Material and type: Sandwich of aluminum and fiberglass-reinforced polymer with pre-engineered installation system

Transmittance: 75 to 80% solar transmittance by ASTM 424 Method B

Index of refraction: 1.58

Weight: Ranges from .75 to 1.5 lb/ft^2

Tensile strength: 10,000 psi

Impact strength: 28 ft-lb (standard); 60 ft-lb (optional)

Coefficient of thermal expansion: 1.4 in/in/°F x 10^{-5} by ASTM D-696

Flammability: Flamespread < 200, smoke < 450 by ASTM E-84-77

Surface weathering characteristics: Good resistance/field refinishable

Maximum continuous service temperature: 200°F

Thermal degradation: 3000 hr at 200°F = 3% transmission loss; 3000 hr at 250°F = 3%, 300 hr at 300°F = 9%

Ultraviolet degradation: 12-mo actual exposure in southern Florida = 1% transmission loss

Optical clarity: Partially translucent (standard)

Standard sizes available: Span capability to 8 ft 6 in; consult manufacturer

Limitations: Maximum service temperature 200°F

PRODUCT DESCRIPTION

Sunwall^{R} is the Kalwall^{R} panel system composed of fiberglass reinforced polymer Sun-Lite^{R} face sheets permanently bonded to a supporting aluminum grid core. These sandwiched panels have a maximum operating temperature of 200°F.

Features: Clamptite^{R} aluminum installation system.

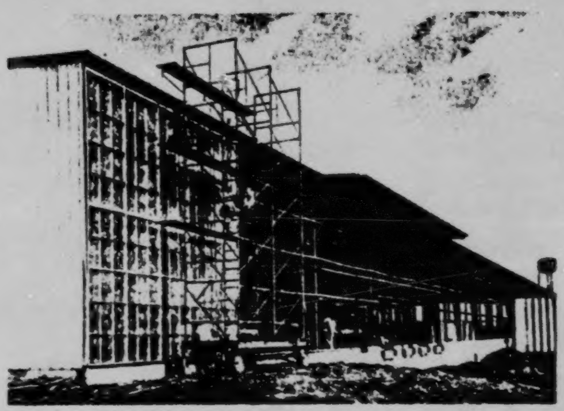
Options: Intermediate glazing layers; partially translucent (standard) or transparent. S.E.I. of 77, 70, 65%; "U" valued of .41, .35, .28 respectively.

Installation Requirements: Complete instructions available.

Maintenance Requirements: Cleaning and field applied weatherable surface coating at 10-yr. intervals.

Guarantee/Warranty: 1-yr. materials and workmanship.

Suggested List Price: $5.00 to $8.00/ft.^{2}



(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

FRESNEL LENS GLAZING

Lectric Lites Co.
2504 W. Vickery Blvd.
Fort Worth, TX 76102

Dr. Richard Claytor (817) 332-7961

TECHNICAL SPECIFICATIONS

Material and type: Optical grade acrylic plastic

Transmittance: 92%

Index of refraction: 1.49

Weight: .74 lbs/ft^2

Tensile strength: 8,000 - 11,000 psi

Impact strength: 0.4 - 0.5 ft lb/in of notch (Izod test, 1/2 in x 1/2 in notched bar)

Coefficient of thermal expansion: 3-5 x 10^{-5} /°F

Flammability: Slow (0.9 - 1.2, ASTM D635)

Surface weathering characteristics: Nil

Maximum continuous service temperature: 175°F

Thermal degradation: Nil

Ultraviolet degradation: Nil

Optical clarity: Transparent

Standard sizes available: 11 in sq in 7 in to 24 in focal lengths; 12 in, 15 in, 17 in, 19 in round in focal lengths from 12 in to 24 in; 16 in x 20 in in 40 in focal length

Limitations: None

PRODUCT DESCRIPTION

Flat optical grade acrylic plastic Fresnel lenses in various focal lengths and sizes, suitable for glazing concentrating solar collectors.

Features: Standard catalog items, usually available from stock.

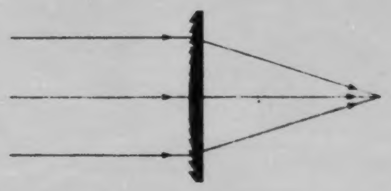
Options: Can be custom cut to desired size.

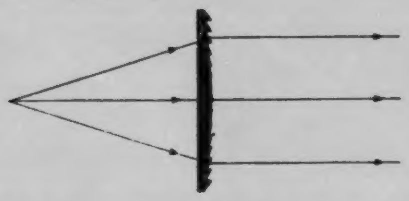
Installation Requirements: None.

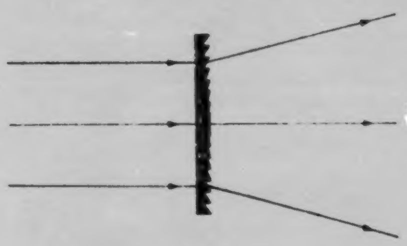
Maintenance Requirements: None.

Guarantee/Warranty: Guaranteed against defects in material and workmanship for 30 days from date of shipment.

Suggested List Price: Ranges between 0.1 and 0.3 dollars per square inch.







(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

QUALEX^R DOUBLE WALL POLYCARBONATE GLAZING

Structured Sheets, Inc.
196 E. Camp Ave.
Merrick, NY 11566

T. Silver (516) 546-4868

TECHNICAL SPECIFICATIONS

Material and type: Lexan^R polycarbonate, UV resistant, flame retardant resin

Transmittance: See table

Index of refraction: Not available

Weight: See table

Tensile strength: 4 mm thick: parallel to ribs, 767 psi; perpendicular to ribs, 568 psi

Impact strength: Falling Dart (1/2" in radius tip), 200 ft-lb

Coefficient of thermal expansion: 3.75 in/in/°F x 10^{-5}

Flammability: ASTM E-84-77: flame spread, 5; fuel contribution, 0; smoke density, 40

Surface weathering characteristics: Abrasion resistance: Taber 17/1000, ASTM 1044, (10)

Maximum continuous service temperature: -22 to 240°F

PRODUCT DESCRIPTION

QUALEX^R is an energy conserving solar glazing. It is a "Polycarbonate Structured Sheet" having a hollow profile and is manufactured from an extra high UV resistant, flame retardant grade of G.E. Lexan^R resin. Suitable for collectors, greenhouses, solar roofs, Trombe walls and site built installations.

Features: Strength to weight ration is 2:1 vs. solid polycarbonate sheet.

Options: Thicknesses are 4, 5, 6 mm and extra strength 7, 8 and 10 mm. Widths up to 1700 mm (66.9 in.). Lengths up to 11.89 m (39 ft.). Clear, opal, solar bronze and special colors.

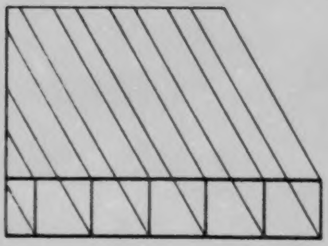
Installation Requirements: Allow coefficient of thermal expansion allowance of 1/32 in/ft.

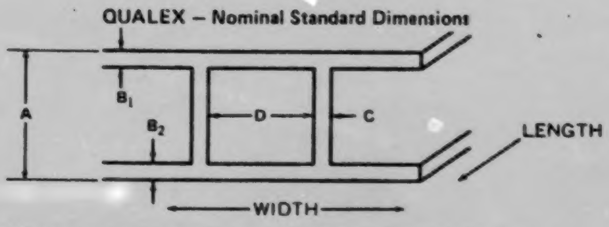
Maintenance Requirements: None.

Guarantee/Warranty: None.

Suggested List Price: \$1.25 to \$2./ft.², depending on gauge and quantity.

Aluminum extrusion mounting profiles are also available.





QUALEX – Nominal Standard Dimensions

A		$B_1=B_2=C$		D		Weight		Width		Length	
in.	mm.	in.	mm.	in.	mm.	lb/ft²	Kg/m²	in.	mm.	[illegible]	m
.157	4	0.014	0.35	0.209	5.3	0.22	1.08	66 15/16	1700	Up To 39	11.9
.197	5					0.23	1.12				
.236	6					0.25	1.22				
.276	7	0.016	0.40	0.209		0.31	1.50				

**QUALEX® is a product of Q Co. Ltd.*
***LEXAN® is trademark of General Electric Co.*

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

CAST ACRYLIC FRESNEL LENSES

Swedlow, Inc.
12122 Western Ave.
Garden Grove, CA 92645

Bill Yamaguchi (714) 893-7531

TECHNICAL SPECIFICATIONS

Lens geometry: Flat, plano surface up, aspheric/acylindrical; f/0.85 min

Concentration ratio: Up to 2000 suns, depending on application

Dimensions: Up to 4 x 8 ft arrays

Thickness: 3/16 to 1/2 in

Applications: Photovoltaic and photothermal

Material: Swedlow S360 cast acrylic

Service life: 20 yr data (from Sandia Labs Report SAND 74-0241 and subsequent data)

Lens efficiency: Approx 85%

Operating temperature: 180°F max

Tracking requirements: Better than 1/4 degree

PRODUCT DESCRIPTION

Fresnel lenses for photovoltaic and photothermal systems. 20-yr. projected life.

Features: Cast acrylic weatherability, custom designed lens performance, large sizes.

Options: System performance predictions, tracking and mounting recommendations, lens performance testing.

Installation Requirements: Accurate solar tracking and mounting frames are required.

Maintenance Requirements: Periodic cleaning.

Guarantee/Warranty: Negotiated on a per-order basis.

Suggested List Price: Approximately \$3.50 to \$4./ft^2 in quantity production.

Availability: Approximately 6 mos. to first article.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

Solar Products Specifications Guide

POLY-GLAZ POLYCARBONATE SHEET

Sheffield Plastics Inc.
Salisbury Rd.
Sheffield, MA 01257

Tom Kradel (413) 229-8711

TECHNICAL SPECIFICATIONS

Material and type: Light stabilized polycarbonate

Transmittance: 0.85

Index of refraction: 1.59

Weight: 0.125 in, 0.78 lb/ft^2; 0.060 in, 0.38 lb/ft^2

Tensile strength: 9000 psi

Impact strength: Unnotched, no failure; notched 1/8 in thick, 16 ft-lb per inch of notch

Coefficient of thermal expansion: 3.75×10^{-5} in/in/°F

Flammability: Self extinguishing ASTM D-635

Surface weathering characteristics: Slight yellowing and hazing after 5-yr (not abrasion resistant)

Maximum continuous service temperature: 250°F

Thermal degradation: Not available

Ultraviolet degradation: Not available

Optical clarity: Transparent

Standard sizes available: 6 x 8 ft, 0.030 to 0.5 in thick

Limitations: Soluble in chlorinated hydrocarbons, partly soluble in aromatic hydrocarbons. Should not be used in environments where combination of heat and moisture exceed 212°F and 50% relative humidity

Other important characteristics: See reverse side

PRODUCT DESCRIPTION

Poly-Glaz is a thermoplastic glazing material with primary properties of high impact strength, heat resistance and clarity.

Features: Impact resistance.

Options: None.

Installation Requirements: Use non-hardening sealants such as silicone rubber and allow for thermal expansion and contraction.

Maintenance Requirements: Use mild detergents and non-abrasive cleaning materials to avoid scratching. Hose with clear water, allow to air dry.

Guarantee/Warranty: None.

Suggested List Price: Contact distributors for quantity prices.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

POLY-GLAZ POLYCARBONATE SHEET

DIMENSIONAL REQUIREMENTS FOR GLAZING

(Based on 40 psf, wind loading is shown in the following table)

SASH DIMENSION	RECOMMENDED POLY-GLAZ THICKNESS	MIN. EDGE ENGAGEMENT	MIN. RABBET DEPTH	MIN. RABBET WIDTH	MIN. SEALER TAPE THICKNESS
12 x 12	0.093	¼	⁵⁄₁₆	⅜	⅛
12 x 18	.093	¼	⁵⁄₁₆	⅜	⅛
16 x 16	.093	¼	⁵⁄₁₆	⅜	⅛
18 x 24	.125	⁵⁄₁₆	⅜	⅜	⅛
18 x 36	.125	⁵⁄₁₆	⅜	⅜	⅛
24 x 24	.125	⅜	½	⅜	⅛
24 x 36	.125	⁷⁄₁₆	⁹⁄₁₆	½	⅛
24 x 48	.125	⁷⁄₁₆	⁹⁄₁₆	⅝	¼
36 x 36	.125	¾	1	⅝	¼
36 x 48	.187	¹³⁄₁₆	1	¹¹⁄₁₆	¼
36 x 72	.187	¹³⁄₁₆	1	¹¹⁄₁₆	¼
48 x 48	.187	¹³⁄₁₆	1	¹¹⁄₁₆	¼
48 x 72	.250	1	1¼	¹¹⁄₁₆	¼
48 x 96	.250	1¹⁄₁₆	1⅜	¾	¼

TYPICAL PHYSICAL PROPERTIES OF POLY-GLAZ SHEET

PROPERTY	ASTM METHOD	UNITS	ALL GRADES
Specific Gravity	D-792	—	1.2
Specific Volume	D-792	cu in/lb	23
Tensile Strength, yield	D-638	psi	8000-9500
Tensile Strength, ultimate	D-638	psi	9000-11500
Elongation, ultimate	D-638	%	100-130
Ten. Mod. of Elasticity	D-747	psi x 10^5	3.4
Flexural Strength	D-790	psi x 10^3	12.2-12.7
Flexural Modulas	D-790	psi x 10^5	3.2-3.5
Compression Strength	D-695	psi x 10^3	12.5
Izod Impact Strength (on STD Molded ⅛" Specimen)	D-256	ft lbs/in notch	14.0-17.5
Hardness, Rockwell	D-785	—	R115
Thermal Conductivity	C-177	10^{-4}cal/(sec)(cm^2)(°c)/CM	4.6
Specific Heat	—	—	0.28
Thermal Expansion	D-696	10^{-5}in/in/°c	7.0
Heat Distortion Temp. 264 psi	D-648	°F	265-285
Water Absorption, 24 hrs	D-570	%	0.14
Refractive Index	D-542	n_d	1.586
Transmittance	D-1003	%	82-89
Burning Rate	D-635	in/min	Self-Extinguishing

QUALEX^R DOUBLE WALL POLYCARBONATE GLAZING

TECHNICAL SPECIFICATIONS (cont.)

Thermal degradation: Heat distortion temp, 284°F

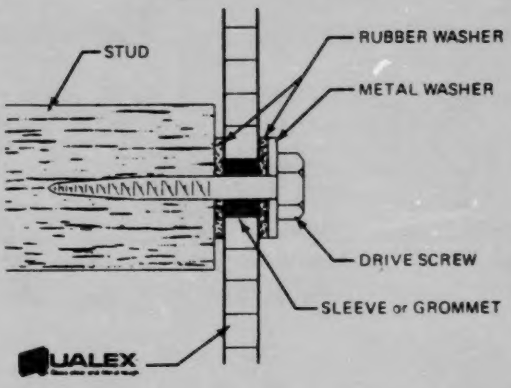
Ultraviolet degradation: Extrapolation of 3-yr outdoor and xenotest 1200 indicates a max of less than 1% loss of light transmission per yr or 10% for 10 yr due to yellowing

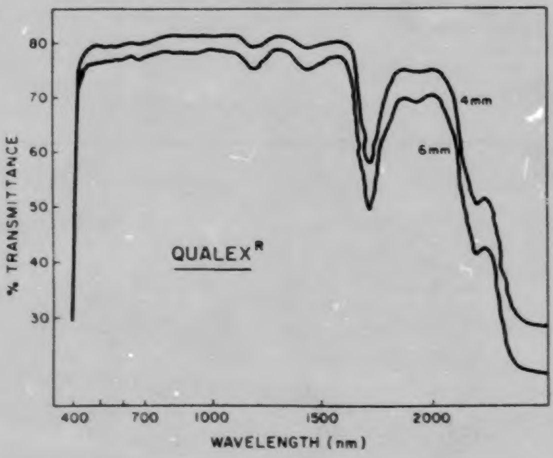
Optical clarity: Transparent (clear and solar bronze) or translucent - (opal)

Standard sizes available: 4, 5, 6, 7, 8 & 10 mm thick, widths to 1700 mm, lengths to max 39 ft

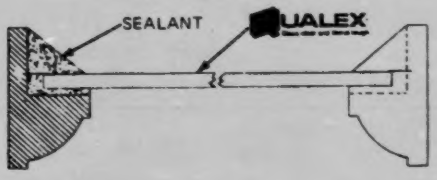
Limitations: Min radius of curvature is 1,000 x thickness (perpendicular to ribs)

Fastener Installation

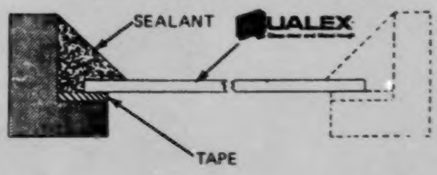

STUD
RUBBER WASHER
METAL WASHER
DRIVE SCREW
SLEEVE or GROMMET
QUALEX



Installation in Wood Sash


SEALANT
QUALEX

Installation in Metal Sash


SEALANT
QUALEX
TAPE

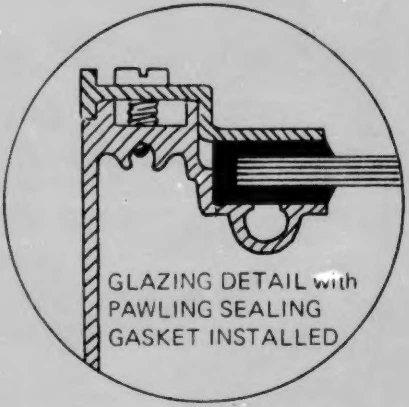
(This information is provided by the manufacturer, who is responsible for technical accuracy.)

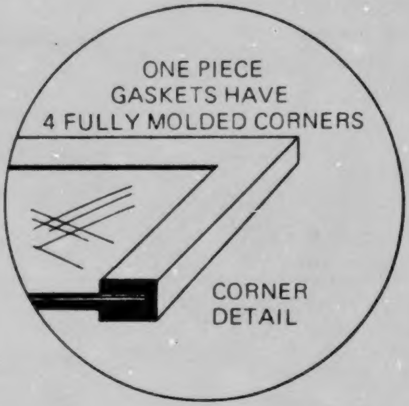
Solar Products Specifications Guide

RUBBER, SILICONE GLAZING GASKETS & SEALS

Pawling Rubber Corp.
157 Maple Blvd.
Pawling, NY 12564

Stephen J. Smith (914) 855-1000


GLAZING DETAIL with
PAWLING SEALING
GASKET INSTALLED


ONE PIECE
GASKETS HAVE
4 FULLY MOLDED CORNERS
CORNER
DETAIL

PRODUCT DESCRIPTION

Rubber & silicone seals as well as manifold (header) grommets for use in solar collectors. Product used to isolate absorber plates, seal glazing, etc.

Features: Hi-temperature materials.

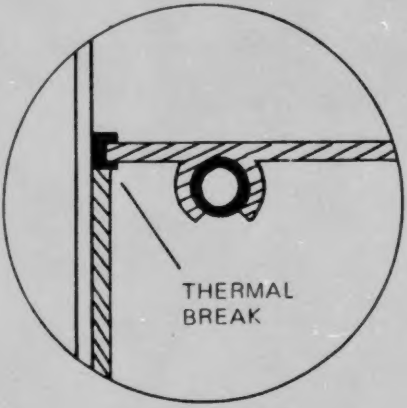
Options: Choice of material.

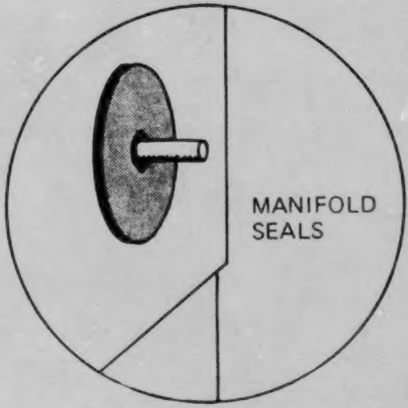
Installation Requirements: Not applicable.

Maintenance Requirements: None.

Guarantee/Warranty: Inasmuch as Pawling Rubber Corp. has no control over the use to which others may put the material, it does not guarantee that the same results as those described herein will be obtained. Each user should make his own tests to determine the material's suitability for his own particular application.

Suggested List Price: Dependent on material selection and other customer specifications.


THERMAL
BREAK


MANIFOLD
SEALS

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

RUBBER, SILICONE GLAZING GASKETS & SEALS

COMPARATIVE DATA

Resistance To:	Pawling E633 EPDM Ethylene Propylene Polymer	Pawling 80623 Silicone Pawling 96-B-24 Silicone Polysiloxane Polymer
Water Absorption	Excellent	Excellent
Oxidation	Excellent	Excellent
Ozone	Outstanding	Outstanding
Sunlight Aging (Ultra Violet)	Outstanding	Excellent
Heat Aging	Excellent	Outstanding
Low Temperature	Excellent	Outstanding
Temperature Range	−60°F to +300°F*	−60°F to +500°F*
Rebound Hot	Excellent	Excellent
Cold	Excellent	Excellent

* These temperature ranges are recommended limits for normal service life. Occasional or intermittent temperature exposure above these limits may cause slight accelerated heat aging which results in some hardening and loss of flexibility of that portion of the part exposed to the high temperature. However, the seal will not cease functioning.

Volitalization (outgassing) – Used as recommended, outgassing of E633 EPDM, 96-B-24 and 80623 silicone is *infinitesimal.* No measurable light transmission degradation has been noted in the field or laboratory.

96-B-24 and 80623 SILICONE

Specification ASTM D2000 5GE608

$A_{19}B_{37}C_{12}EA_{14}EO_{16}EO_{36}F_{110}PZ_1Z_2Z_3Z_4$

Original Properties:	**As Specified**	**As Obtained**
Durometer (Shore A)	60 ± 5	60
Tensile Strength	Min. 700 psi	900 psi
Elongation	Min. 200%	225%
Oven Aged 70 Hrs @ 437°F (A_{19})		
Durometer Change	Max. +10	+4
Tensile Change	Max. −25%	+3%
Elongation Change	Max. − 30%	−7%
Compression Set 22 Hrs @ 347°F (B_{37})		
% Deflection	Max. 25%	20%
Water Immersion 70 Hrs @ 212°F (EA_{14})		
Volume Change	± 5%	+0.5%

Ozone Resistance 168 Hrs @ 50 PPHM +104°F @ 20% Strain (C_{12})

No Cracking or Checking – Passed

Cold Test, Flexibility Brittle Point @ −85°F (F_{110})

No cracking before or after impact – Passed

Staining Test: Non-staining as per ASTM D 925, method B – Non-staining (P)

Special Tests: Samples baked 14 days @ 350°F in a tightly covered 500 ml Berzelius Beaker on a hot plate

Z_1 – Maximum weight loss 0.04%

Z_2 – No appreciable fogging of glass cover plate or beaker sides.

Z_3 – Maximum +5 durometer change (Shore A)

Z_4 – No cracking when flexed 180° several times.

E633 EPDM

Specification ASTM D2000 3BA 620 $A_{14}B_{13}C_{12}F_{17}Z_1Z_2Z_3Z_4Z_5$

Original Properties:	**As Specified**	**As Obtained**
Durometer (Shore A)	60 ± 5	60
Tensile Strength	Min. 2000 psi	2200 psi
Elongation	Min. 400%	425%
Tear Resistance (G_{21})	-----	200
Oven Aged 70 Hrs @ 212°F (A_{14})		
Durometer Change	Max. +10	+5
Tensile Change	Max. −25%	−4%
Elongation Change	Max. −25%	−10%
Compression Set 22 Hrs. @ 158° (B_{13})		
% Deflection	Max. 25%	20%
Water Immersion 70 Hrs. @ 212°F (EA_{14})		
Volume Change	+10%	+0.5%

Ozone Resistance 168 Hrs. @ 50 PPHM + 104°F @ 20% Strain (C_{12})

No Cracking or Checking – Passed

Cold Test, Flexibility Brittle Point @ −40°F (F_{17})

No cracking before or after impact – Passed

Special Tests: Samples baked 7 days @ 250°F in a tightly covered 500 ml. Berzelius Beaker on a hot plate (Z_1 – Z_4)

Z_1 – No oily emissions, fogging or crystalline formations within the beaker or on the glass cover plate.

Z_2 – Maximum weight loss 1.0%

Z_3 – Maximum +5 durometer change (Shore A)

Z_4 – No cracking when flexed 180° several times

Special Test: Tear resistance. (Z_5)

Z_5 – Tear resistance (ASTM D 624, Die C) minimum 200 p.i.

(This information is provided by the manufacturer, who is responsible for technical accuracy.)

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

MATERIAL COATINGS, MATERIALS COMPATIBILITY

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

MATERIAL COATINGS, MATERIALS COMPATIBILITY

Metal Coatings

Galvanizing is a corrosion resistant coating usually applied to sheet metal and steel. The coating is a layer of zinc applied to the metal by either of two methods. The most common method is done by dipping the metal in an acid bath for cleaning and then dipped in the molten zinc. In the other method, the coating is applied by an electroplating process, distinguished by its gray color. The electroplated zinc coating is the better choice if the surface is to be painted. Reference the module on Sheet Metal for applications of galvanized steel.

Electroplating is done for corrosion prevention as well as enhancing the appearance of the material. Chromium plated steel and plastics are common in manufacturing processes today. Anodized aluminum can be done in several colors providing protection from oxidation and esthetic appeal.

One electro-plating process common to the Solar industry is the black chrome surface of absorber plates which is applied over a nickel surface on copper which was also accomplished by electroplating.

Vapor deposition is a plating process for very exotic materials where extremely thin coating are applied. This process is usually done in a controlled atmosphere and deep vacuum. Optical lenses, glass surfaces, camera lens, telescop lens and mirrors are coated using this process.

Absorber Coating Properties

Absorber materials serve to absorb and simulatneously transform solar radiation into usable heat and to direct that heat to a heat sink. These two distinct functions may be carried out by one material (the absorber plate) or by different materials (the absorber plate with an absorber coating). Although an absorber coating is not necessary for a solar heating system to operate, most systems do use coatings to enhance energy collection and thereby increase system efficiency. These coatings include dark paints and thin layers of metallic compounds put down by electroplating or other chemical methods.

Typical uses of absorber materials for both passive and active solar systems are illustrated in figure 8-1. In a passive system the thermal storage media itself may serve also as the absorber plate, with dark paint applied to the surface to serve as the coating. In an active system, a glass, plastic, or metal absorber tube or plate, usually with an absorber coating, collects the solar energy and channels the heat to the heat transfer fluid.

How well an absorber coating functions is determined by the amount of solar energy that is absorbed and the amount of the longwave (heat) energy that is emitted. For maximum system efficiency, all the solar energy would be absorbed and there would be no loss due to emission of longwave energy. In reality, however, only a fraction of the solar energy is absorbed, and longwave emission does occur. The fraction of solar energy that is absorbed is designated by the absorptance, denoted by A; the higher the absorptance, the more energy is absorbed. The relative amount of longwave energy that is emitted is indicated by the emittance, denoted by E; the higher the emittance, the more energy is emitted. Absorptance and emittance for coatings are listed in Tables 8-1 and 8-2.

Selective coatings, which have high absorptance and low emittance, result in higher operating and stagnation temperatures than do nonselective coatings, which have high emittance as well as high absorptance. For an active system without glazing on a normal sunny day, the theoretical stagnation temperature is 465^{o}F for a selective coating (A = 0.85, E = 0.20) and 195^{o}F for a nonselective coating (A = 0.95, E = 0.90). In actual use, glazing would increase these temperatures while convection due to air movement would lower them. During normal operation with heat transfer fluid flowing, the temperature also depends on the rate of heat transfer fluid flow, heat transfer fluid temperature, and absorber plate material and configuration. In principle, the higher the operating temperature of a solar collector, the more energy can be transferred to storage. However, high operational temperatures may lead to problems such as thermal degradation of system components and difficulties associated with the different thermal expansion of the various system materials.

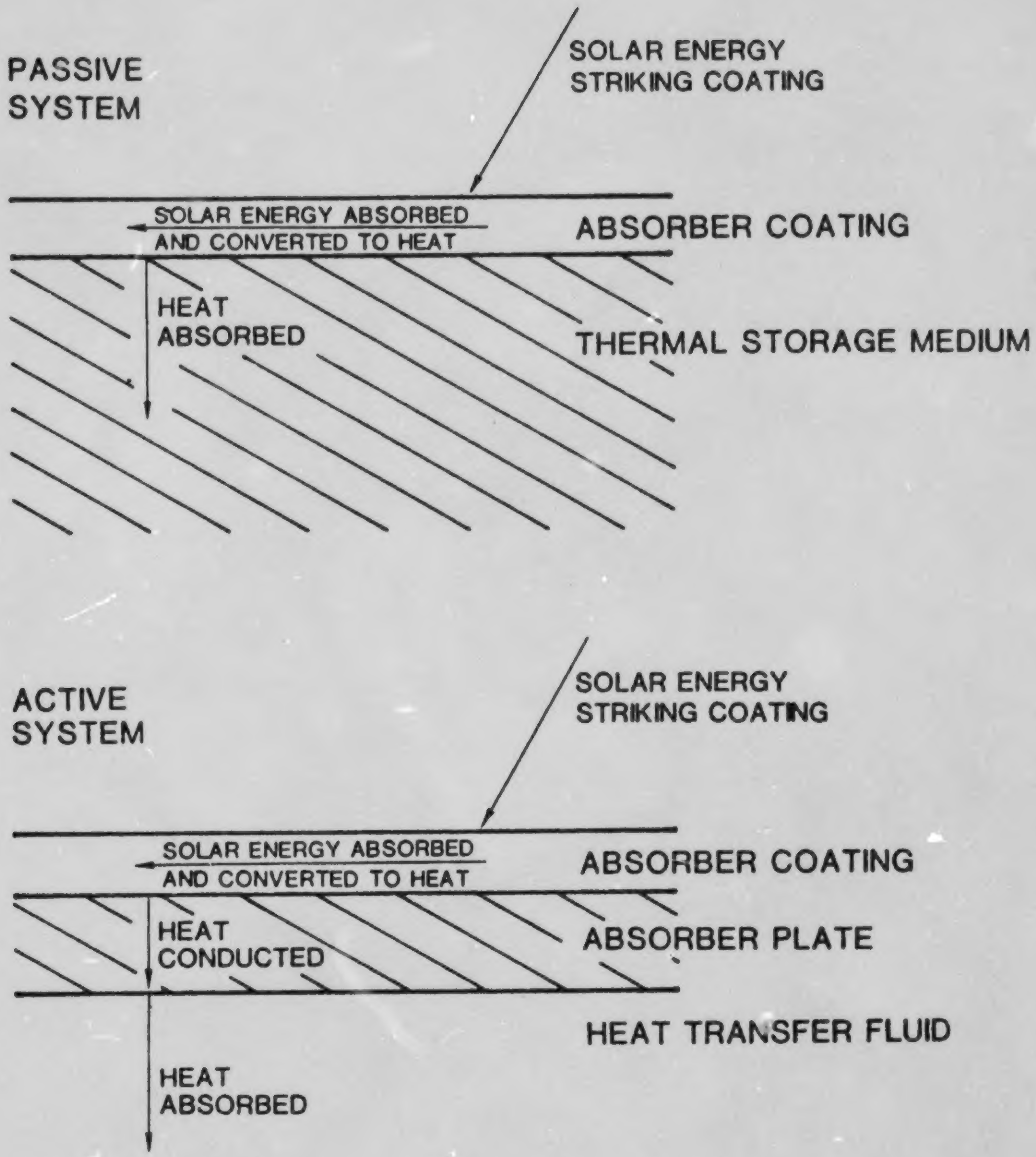

PASSIVE SYSTEM
SOLAR ENERGY STRIKING COATING
SOLAR ENERGY ABSORBED AND CONVERTED TO HEAT
ABSORBER COATING
HEAT ABSORBED
THERMAL STORAGE MEDIUM
ACTIVE SYSTEM
SOLAR ENERGY STRIKING COATING
SOLAR ENERGY ABSORBED AND CONVERTED TO HEAT
ABSORBER COATING
HEAT CONDUCTED
ABSORBER PLATE
HEAT TRANSFER FLUID
HEAT ABSORBED

Figure 8-1. Typical functions of absorber materials in passive and active systems

Table 8-1. Absorptance and emittance of nonselective absorber coatings

COATING	A	E	REFERENCE
Anodized aluminum	0.95	0.80	Krupnick et al (1978)
Black paint	0.95 to 0.98	0.88 to 0.89	Decorative Products Division (1973), PPG Industries (1976)
Black paint	0.90	0.60	Chamberlain Manufacturing Corporation (1976)
Urethane resin over epoxy primer	0.97	0.92	DeSoto Inc. (1977)

Table 8-2. Absorptance and emittance of selective absorber coatings

COATING	SUBSTRATE	A	E	REFERENCE
Aluminum oxide and molybdenum dioxide		0.9	0.1 to 0.4	Melamed and Kaplan (1977)
Black chrome (Chromium metal and chromium oxide)	Nickel-plated metals, copper, steel	0.91 to 0.96	0.07 to 0.16	Mar (1978), Chamberlain Manufacturing Corporation (1976), Krupnick et al (1978)
Black copper (Cupric oxide and cuprous oxide)	Copper, nickel, aluminum	0.81 to 0.93	0.11 to 0.17	Mar (1978), Gore and Quershi (1977)
Black nickel (Nickel oxide)	Nickel, iron, steel	0.89 to 0.96	0.07 to 0.17	Mar (1978), Gore and Quershi (1977)
Cuprous sulfide		0.79		Mattox and Sowell (1974)
Iron oxide	Iron, steel	0.85	0.08	Mar (1978)
Lead oxide		0.98 to 0.99	0.22 to 0.40	Ametek, Inc. (1978)
Lead sulfide in silicone binder		0.94		Mattox and Sowell (1974)
Stainless steel oxide	Stainless steel	0.89	0.07	Krupnick et al (1978)
Selective paint (Honeywell)	Any	0.90	0.30	Mar (1978)
Sulfamate nickel oxide	Stainless steel			Krupnick et al (1978)

Paints

Types of paint. So many new paints have been introduced in recent years that it is difficult for nonprofessionals to be sure when and where particular types should be used. The most significant innovation is water-thinned latex paints.

The common belief that latex means rubber-based is wrong, for latex paint contains no rubber. Latex means here what the dictionary calls it - a whitish, milky emulsion. All latex paints (1) thin with water; (2) dry quickly, usually in about an hour; (3) spread easily; and (4) have little or no "paint" odor. Also the brushes used with them can be cleaned with warm water and soap.

Most manufacturers state on their labels the uses to which their products should be put, and what preparations each requires. Remember, multipurpose paints represent a compromise. A flat finish, even if labeled "washable", cannot be scrubbed the way a high-gloss or semi-gloss enamel can be. Though many paints are labeled flat enamels, this is really a misnomer. They may be washable compared to old-style flats, but you still cannot scrub them repeatedly as you can a semi-gloss or glossy enamel.

Paints are divided into interior and exterior types. Interior types and their uses are described here.

For interior work there are three types of paint - flat, semi-gloss and high-gloss enamel.

Flat paints come in alkyd and latex types. The once popular oil-base flats are seldom seen any more. Both latex and alkyd types are quick-drying and free of odor; the latter has more hiding power than you would get from a latex flat. Alkyd paints are thinned with a paint thinner or turpentine.

In addition to high-gloss types, enamels are also available in a semi-gloss or satin finish, and a duller luster. Enamels will take more scrubbing and abuse than flats. They are available in both alkyd and oil-base types, but latex enamels are available only in semi-gloss.

Deck paints are enamel-type finishes sometimes used on interior surfaces. The most widely used are varnish-based, which dry to a high gloss.

How to use color. Color is the least expensive way to insure esthetic appeal and paint is by far the most economical mehtod.

The more you know about color, the more effective use you can make of it. Get to know colors, and the color wheel which is a color spectrum arranged in a circle. Fill in the circles with crayons or water colors in the indicated colors, and you will have a practical working tool.

You will recognize the three primary colors, yellow, blue and red and the secondary hues (formed by pairing the primaries), orange, purple and green. The others are mixtures of primaries and secondaries, called tertiaries. Using tints, tones, and shades of these twelve basic hues, you can work color magic.

By combining the colors on the wheel as shown by the arrows, you will get various harmonious effects. Whether you wish to stay with this conventional harmony or change color "keys" depends on your personal taste. The use of the color wheel to obtain a limited range of predictable harmonious effects assures you of a non-clashing color scheme.

Paint styling is the technique of using color for emphasis on a piece of furniture, and to minimize the unattractive ones. An important facet of paint styling is the creation of optical illusions. Suppose two identical house are built side by side on adjoining plots. If one is painted in light colors and the other in dark, the light house will seem larger.

The same principle also works indoors. If you paint the walls and ceiling in a light tint, the room will seem more expansive than it would in a dark tone. The "largest" of the colors is yellow, followed by red, then green, blue and finally black.

This "fool the eye" principle can be applied in other ways to problems inside and outside a **home**, particularly in choice of trim color for a collector array.

A light-colored roof that seems too high for its width can be lowered to scale by the use of dark-colored shingles.

Finally, color can give unity to a house. If too great a variety of building materials has been used in its construction, for example, the use of a single paint color can do much to unite all the materials into a harmonious whole.

Choosing the right paint. Different surfaces require different paints, so the type you choose depends on the surface to be painted. For wood siding, use a conventional oil-base paint, an alkyd-base paint, or latex paint. Shingle stain is recommended for shingles and shakes. Use an exterior latex paint for asphalt siding; asphalt will not bleed through latex. Paints for masonry houses must be resistant to the alkali present in concrete and mortar; exterior latex paints, solvent-thinned masonry paints, colorless silicone-base water repellents, and Portland cement paints (over unpainted concrete only) are recommended.

Trim paints are glossy, enamel-like finishes for windows, doors, and other exterior trim. They have a varnish or alkyd resin base, and dry to a hard, dense finish. Deck paints are enamel-type finishes used on porch floors, steps, patios, and terraces. The most widely sold varieties are varnish-based, which dry to a hard gloss. For concrete surfaces, latex and chlorinated rubber-base paints are suitable.

Latex paints are easy to apply, and the surface to which they are to be applied need not be absolutely dry. Their quick-drying qualities keep down dirt and bug collection during drying and make it possible to apply a second coat within an hour or two. They give a good-looking, long-lasting finish and, since latex paints are generally permeable to moisture, are less likely than oil-base paints to blister.

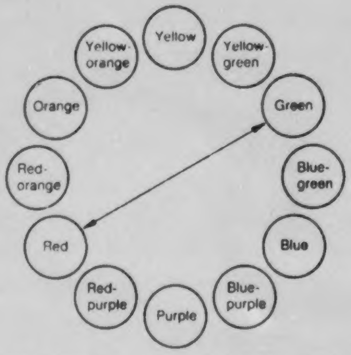
Many of the new house paints are designed to be self-cleaning; they chalk gradually and rain washes away the outer layer to which dirt adheres, keeping the paint fresh and bright. If there is masonry or a darker color below upper portions of your home, chalking paints will stain the lower areas. In this case, use non-chalking paint for the upper surfaces.

Location is another factor you must consider in choosing the proper paint. In an area where atmospheric conditions might cause mildew, a paint with a mildew-resistant additive should be used; this will constitute an effective barrier against mildew. Additives must, of course, be compatible with the ingredients of a particular paint. Your paint dealer can assist you in matching additives to particular brands.

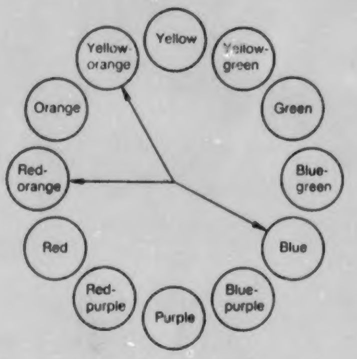
The most suitable protective coatings for the items listed in the left-hand column are shown in this chart. A solid block means that the product listed directly above it is recommended. For example, for kitchen and bathroom walls, follow the line to the solid blocks, look above them, and you will find the recommended products.

	Semi-gloss—latex	Flat paint—latex	Flat paint—alkyd-type	Semi-gloss—alkyd	Gloss enamel—alkyd	Rubber-base paint (not latex)	Interior varnish	Shellac	Wax (liquid or paste)	Wax (emulsion)	Stain	Wood sealer	Floor varnish	Floor paint or enamel	Aluminum paint	Sealer or undercoat	Metal primer	Cement-base paint	Clear polyurethane	Catalyzed enamel
Dry walls	●	●	●	●	●			■				■				■				●
Plaster walls and ceilings	●	●	●	●	●	■										■				●
Wallboard	●	●	●	●	■	■										■				●
Wood paneling	●		●	●	■	■	■	■	■		■	■							■	■
Kitchen and bathroom walls	●			●	■	■										■				■
Wood floors						■		■	■	●	●	■	●	●					■	■
Concrete floors						■			●	●	■			■				■	■	■
Vinyl and rubber tile floors									■	■										
Asphalt tile floors										■										
Linoleum								■	■	■			■	■						
Stair treads						■		■			■	■	■	■					■	■
Stair risers			●	●	●	■	■	■			■	■							■	■
Wood trim	●		●	●	●	■	■	■	■		■					■			■	■
Steel windows	●		●	●	●	■									■		■			■
Aluminum windows	●		●	●	●	■									■		■			■
Window sills	●				●	■	■													■
Steel cabinets			●	●	●	■											■			■
Heating ducts	●		●	●	●	■									■		■			■
Radiators and heating pipes	■		●	●	●	■									■		■			■
Old masonry	■	■	■	■	■	■									■	■		■		■
New masonry	●	●	●	●	●	■										■		■		■

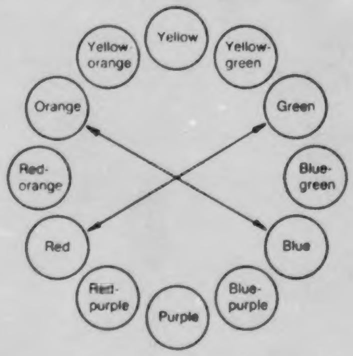
● Black dot indicates that a primer or sealer may be necessary before the finish coat (unless surface has been previously finished).


Yellow
Yellow-green
Green
Blue-green
Blue
Blue-purple
Purple
Red-purple
Red
Red-orange
Orange
Yellow-orange

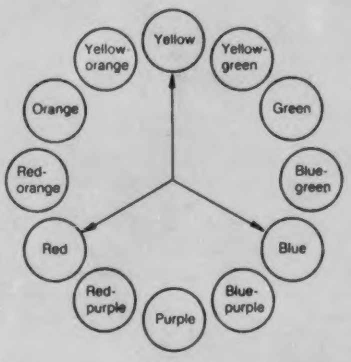
Complementary colors are any two opposite each other on the color wheel. These are familiar contrasts, generally considered harmonious.


Yellow
Yellow-green
Green
Blue-green
Blue
Blue-purple
Purple
Red-purple
Red
Red-orange
Orange
Yellow-orange

Split complementaries are a foolproof way to choose tri-color schemes. Turn the Y pointer 180° for opposite split complementary colors.


Yellow
Yellow-green
Green
Blue-green
Blue
Blue-purple
Purple
Red-purple
Red
Red-orange
Orange
Yellow-orange

Double complementaries combine two pairs of opposite colors and are a sound basis for selecting harmonious four-way combinations.


Yellow
Yellow-green
Green
Blue-green
Blue
Blue-purple
Purple
Red-purple
Red
Red-orange
Orange
Yellow-orange

Triad harmony utilizes three equidistant colors on the color wheel, achieves variety by using different tints of principal colors.

Use this chart to determine the best protective coating for any of the outdoor, around-the-house items listed in the left-hand column. For example, for shutters and other trim, follow the line to the solid blocks, and look above them, for recommended products.

	Exterior masonry paint—latex	House paint—latex	House paint—oil-base	Transparent sealer	Cement-base paint	Exterior clear finish	Aluminum paint—exterior	Wood stain	Roof coating	Roof cement	Asphalt emulsion	Trim paint	Awning paint	Spar varnish	Porch-and-deck enamel	Primer or undercoat	Metal primer	Latex types	Water-repellent preservatives
Wood siding		■	●				■									■		●	
Brick	■	■	●	■	■		■									■		■	
Concrete block	●	■	●	■	■		■									■		■	
Asbestos cement	■	■	●													■		■	
Stucco	■	■	●	■	■		■									■		■	
Natural wood siding and trim						■		■						■					
Metal siding		■	●				●					●					■	●	
Wood frame windows		●	●				■					●				■		●	
Steel windows		●	●				●					●					■	●	
Aluminum windows		●	■				■					●					■	●	
Shutters and other trim		●	●									●				■		●	
Canvas awnings													■						
Wood shingle roof								■											■
Metal roof		●	●														■	●	
Coal tar-felt roof									■	■	■								
Wood porch floor															■				
Concrete porch floor															■			■	
Copper surfaces														■					
Galvanized surfaces		●	●				●					●					■	●	
Iron surfaces		●	●				●					●					■	●	

● Black dot indicates that a primer or sealer may be necessary before the finish coat (unless surface has been previously finished).

Material Compatibility

Many of the components of a solar heating system come in contact with one another. This may occur during normal operation of the system or during abnormal conditions such as system failure (Table 2-2). Ideally, the components of a solar heating system would not interact chemically when in contact. In practice, however, they do. This can result in changes in properties or formation of new compounds. Degradation of system performance and safety can result. Two common sources of incompatibility are corrosion and outgassing.

Corrosion is the wearing away of a material by chemical reaction, dissolving, or physical process. Corrosion of metals can be caused by chemicals in heat transfer fluids and insulation. Water enhances and is often required for corrosion of metals. Corrosion may result in leakage, interference of fluid flow, loss of strength of materials, and malfunction of temperature sensors. Different types of corrosion of metals may occur in solar heating systems:

> Chemical oxidation occurs when oxygen (air) is persent in the system.
>
> Galvanic corrosion occurs between two dissimilar metals when the metals are in direct contact and/or are in contact with a common fluid which supports and conducts electric current, such as water. The metal that is more positive (anodic) will dissolve in the fluid and will be deposited on the more negative metal (Table 2-3).
>
> Pitting corrosion occurs when metallic contaminants in the fluid deposit on a more anodic metal, establishing localized galvanic cells.
>
> Crevice corrosion occurs when the depletion of oxygen in a nonturbulent area results in that area becoming anodic, relative to the remainder of the system.
>
> Erosion corrosion develops when high velocity liquid flow removes the protective surface film from the metals, allowing the metals to corrode by physical and/or galvanic action.

Over time, and particularly at high temperatures, some materials give off volatile substances. These outgassing products are from several sources. Many polymeric materials are synthesized from volatile compounds, and any residual volatiles outgas with time. Some additives in materials are not chemically bonded to the material and are gradually lost to the atmosphere. Foam insulations have gases trapped in them which slowly escape. At high temperatures, materials react and degrade chemically, giving off volatile compounds. The outgassing products from certain materials are quite reactive and corrosive.

Table 2-2. Conditions for contact between materials in an active solar heating system

	HEAT TRANSFER FLUIDS	GLAZING	INSULATION	SEALS AND SEALANTS	THERMAL STORAGE MEDIA	ABSORBER MATERIALS
HEAT TRANSFER FLUIDS		Abnormal	Abnormal	Normal	Abnormal	Normal
GLAZING	Abnormal		Abnormal	Normal	Abnormal	Abnormal
INSULATION	Abnormal	Abnormal		Normal	Abnormal	Normal
SEALS AND SEALANTS	Normal	Normal	Normal		Normal	Normal
THERMAL STORAGE MEDIA	Abnormal	Abnormal	Abnormal	Normal		No Contact
ABSORBER MATERIALS	Normal	Abnormal	Normal	Normal	No Contact	

Table 2-3. Electromotive series for evaluating compatibility of metals

Magnesium	Most anodic, most dissolving
Zinc	
Aluminum	
Tin	
Lead	
Iron	
Copper	
Silver	
Gold	Most cathodic, least dissolving

Operational Compatibility Considerations

The manufacturers' suggested operating ranges and conditions for use of heat transfer fluids in solar applications take into account not only the boiling and freezing (pour) points of the fluid but other factors as well. Of particular concern is the chemical stability. At elevated temperatures fluids may degrade to produce volatile products or nonvolatile polymeric or carbon compounds. In the absence of air, most heat transfer fluids do not degrade appreciably to volatile products, even at 450°F temperatures (Arnold and Trujillo 1979). However, in many systems the heat transfer fluid will be in contact with air, either because of the original design (open system) or because of leaks (closed system originally containing an inert gas). In the presence of air, oxidation of the fluid may occur at elevated temperatures, particularly for the hydrocarbon oils. The chemical stability of the fluids is also influenced by the contact with system materials or contaminants which ast as catalysts for chemical reaction. For example, copper, which is often a piping material in solar heating systems, acts as a catalyst for the chemical degradation of some hydrocarbon fluids.

The other materials in a solar heating system not only affect the heat transfer fluid but are also affected by the fluid. Plastics and metals in the various parts of the plumbing system are the materials most likely to come in contact with fluid under normal operating conditions. Seals in pumps must not react with or be degraded by the heat transfer fluid. Plastic piping is compatible with many heat transfer fluids, but silicone fluids can cause stiffening and hardening of polyvinly chloride pipes. Metal piping is also compatible with many fluids, but particular attention must be paid to the problem of corrosion. Corrosion, once started, usually cannot be stopped, and if it is not stopped, it will ultimately lead to system failure. Unfortunately, it is very difficult to eliminate corrosion from a metal-containing system, but there are a number of ways to slow the process. The following guidelines will aid in creating a system for which the rate of corrosion of the interior portion is minimal:

> Use a minimum number of metals in the system. If there is only one metal, the problem of galvanic corrosion is eliminated.
>
> In multimetal systems, use a getter, that is, pieces of the anodic metal strategically located in the system so that they will dissolve prior to the dissolving of other anodic components. This is known as cathoaic protection.
>
> Use a heat transfer fluid that is compatible with the metals in the system. The manufacturer of the fluid should be able to provide this information.
>
> With aqueous solutions, use fluids which contain anticorrosion additives for the specific metals in the system.

Purge air from the system when adding the heat transfer fluid.

Design the fluid-containing system so that there are no areas where gases can be trapped.

Use distilled or deionized water for diluting glycol-based heat transfer fluids.

Use fluid velocities of less than 2 feet/second.

Additional considerations for the use of specific metals in contact with heat transfer fluids are presneted in Table 3-1.

Table 3-1. **Acceptable and unacceptable use conditions for metals in direct contact with heat transfer fluids**[a]

METAL	ACCEPTABLE CONDITIONS	UNACCEPTABLE CONDITIONS
Aluminum	Distilled or deionized water which contains appropriate inhibitors; aluminum does not contact copper or iron piping. Distilled or deionized water which contains appropriate inhibitors and a means of removing heavy metal ions obtained from contact with copper and iron pipe. Stable anhydrous organic fluids.	Untreated tap water with pH less than 5 or greater than 8. Fluid containing copper, iron, or halide ions. Fluid which is in contact with corrosive soldering fluxes.
Copper	Low carbonate, low chloride tap, distilled, or deionized water. Stable anhydrous organic fluids. Aqueous fluids which do not form copper complexes.	Stagnant corrosive water. Chemicals that can form copper complexes. Fluid which is in contact with corrosive fluxes. Copper surface is locally covered with a copper oxide or carbon film.
Steel	Distilled, deionized, or low salt content water which contains appropriate corrosion inhibitors. Stable anhydrous organic fluids. Cathodic protection of the steel is used. Aqueous fluids of pH greater than 5 or less than 12.	Untreated tap, distilled or deionized water with pH less than 5 or greater than 12. Fluid which is in contact with corrosive fluxes.

(continued)

Table 3-1. continued

METAL	ACCEPTABLE CONDITIONS	UNACCEPTABLE CONDITIONS
Stainless Steel	Low chloride and low carbonate untreated tap, distilled, or deionized water of high oxygen content. Stable anhydrous organic fluids.	Stagnant water, especially containing chloride ions. Water of low oxygen content. Fluid which is in contact with corrosive fluxes.
Galvanized Steel	Cathodic protection of galvanized parts. Water with pH greater than 7 but less than 10.	Aqueous fluid containing copper ions. Stagnant water. Water with pH less than 7 or greater than 12. Water with temperature greater than 130°F and less than 200°F.

---

[a] Data from Ontario Research Foundation. 1977. The development of methods of reducing corrosion in solar collectors. Technical report. Final report no. 7-77. Mississauga, Ontario, Canada.

Compatibility and Degradation

The results of the trapping of heat by glazing are an increase in the temperature of the system and exposure of glazing and associated materials to high temperatures. Glazing may also be exposed to the outdoor atmosphere, to high humidity, and to outgassing products from seals, sealants, and insulation. During normal operation, it may be in contact with seals, sealants, wood, metal, and plastic. During abnormal condiions in active systems, the glazing may come in contact with the absorber plate and the heat transfer fluid.

Incompatibility of polymers has been observed in solar heating systems. Local fogging of cover plates has been noted when there was contact between EPDM rubber and polycarbonate glazing (Skoda and Masters 1977). One possible cause is the incompatibility among plasticizers and polymers. Any given plasticizer is usually compatible with only a limited number of polymeric resins (Plastics Engineering 1978). Contact of different polymers may permit reaction of incompatible substances resulting in softening, hardening, cracking, marring, and fogging. Outgassing substances also may be a source of physical or chemical incompatibility. Fogging of glazing has occurred from outgassing of improperly cured silicone sealant (Skoda and Masters 1977) and absorber coating (U.S. Department of Housing and Urban Development 1978).

Highest collector temperatures can and often do occur during system installation (Brooks et al 1978) because collector plates are exposed to the sun prior to movement of heat transfer fluid through them. This high temperature can cause thermal damage to glazing, outgassing from other materials, and buckling of the absorber plate. Keeping the collectors covered prior to system operation will reduce the probability of damage to the glazing and other components.

Contact between absorber plate and glazing has resulted from warping of the materials (Skoda and Masters 1977). Contact with the hot absorber plate may cause thermal degradation of the glazing, which results in loss of solar energy transmission. Contact may also cause the absorber coating to discolor or crack, resulting in lower solar energy absorption.

Glass Breakage

The principal problem of using glass as a glazing material is breakage, which can occur from both mechanical and thermal stress. To reduce chance of breakage from thermal stress, the following procedures are suggested: use of tempered rather than nontempered glass; use of glass with smooth edges rather than with edges that are not treated after cutting, since the latter have rough spots

Compatibility and Environmental Response Properties

Seals and sealants are exposed to a wide variety of conditions depending on their locations within solar systems. A material that has properties suitable for use can be selected only after careful attention has been given to the environment in which it is to function. To sustain proper functioning of a solar system, a seal or sealant should have the following compatibility and environmental response properties:

Withstand thermal cycling
Resist weathering
Compatible with materials
Undergo minimum outgassing

Thermal cycling - Solar systems undergo wide swings in temperature, -30 to 400°F for flatplate collectors and up to 600°F for concentrating or evacuated tube collectors. The elastomer must have a useful temperature range that is compatible with the temperature fluctuations experienced by the solar system. Table 6-3 summarizes the temperature limits of elastomeric materials.

Weathering - Exposure to the elements can lead to loss of physical properties. Relative humidity, sunlight, rainfall, and air pollutants, in addition to temperature, can affect the lifetime of a specific seal or sealant material. Exposure to sunlight can cause brittleness and loss of elasticity, resulting in fluid leaks and loss of collector efficiency. Some elastomers are inherenlly resistant to UV degradation while others contain UV stabilizers that prevent or slow the degradation process. Ozone is an air pollutant that is prevalent in many urban areas. It quickly attacks and degrades untreated natural rubber, and degrades other elastomers to various extents. Acrylic, nitrile, and natural rubbers require special compounding for weather, ozone, and/or sunlight resistance.

Compatibility - Seals may come in direct contact with metals and heat transfer fluids. Table 6-4 summarizes the resistance of elastomers to degradation by heat transfer fluids. The fluoroelastomers are compatible with all the fluids, while the other elastomers are compatible with only some of the fluids. Table 6-5 summarizes the effect of elastomers on metal and water when they are in contact. Specific formulations of the same generic elastomer had different effects. Some seals and sealants are incompatible with each other: butyl caulk should not be used in contact with silicone caulk (Shertz 1980).

Table 6-3. Temperature limits of elastomers

ELASTOMER/ASTM	SERVICE TEMPERATURE RANGE[a] (°F)	HEAT RESISTANCE
Acrylic/ABR	-20 to 350	
Butadiene/BR	-100 to 175	
Buna-S/SBR	-67 to 200	F
Butyl/IIR	-67 to 250	G-E
Carboxylic/COX	-90 to 275	
Ethylene rubber/EPM		
EPDM	-80 to 300	G-E
Fluoroelastomer/FPM	-40 to 450	E
Hydrin/CO, ECO	-40 to 325	
Hypalon/CSM	-67 to 275	
Isoprene/IR	-80 to 175	
Natural rubber/NR	-80 to 175	
Neoprene/CR	-67 to 250	G-E
Nitrile rubber/NBR	-67 to 275	G-E
Polyblend/PVC-NBR	-30 to 250	
Polysulfide/T	-40 to 225	P-G
Silicone/SI, FSI, PSI VSI, PVSI	-140 to 550	E
Urethane/U	-40 to 250	

---

[a] Data from Harper, C.A. (ed.) 1975. Handbook of Plastics and Elastomers. McGraw-Hill, New York, NY.

P = Poor F = Fair G = Good E = Excellent

Table 6-4. Compatibility of elastomers with heat transfer fluids[a]

ELASTOMER/ASTM	CLASS OF HEAT TRANSFER FLUIDS				
	MINERAL OILS	AROMATIC HYDROCARBON OILS	ETHYLENE GLYCOL	SILICONE OILS	ALKYLATED AROMATIC HYDROCARBON
Acrylic/ABR	G	G	P	G	G
Butyl/IIR	P	P	G-E	F-G	P
Ethylene/EPM	P	P-F	E	E	P-F
EPDM	P	P-F	E	E	P-F
Fluoroelastomer/FPM	E	E	E	E	E
Neoprene/CR	G	P-F	G-E	G-E	P-F
Nitrile/NBR	E	F-G	G-E	G-E	F-G
Polysulfide/T	E	E	P	E	E
Silicone/SI	P-F	P-F	F-E	P-F	P-F

[a] Data from Mernagh. L. R. (ed.) 1969. Rubbers Handbook. Morgan-Grampion, London; and Harper, C. R. 1975. Handbook of Plastics and Elastomers. McGraw-Hill, New York, NY.

P = Poor F = Fair G = Good E = Excellent

Poor - Use of the elastomer in the presence of the indicated agent is not recommended. The effect varies from a catastrophic failure (such as dissolution) to a severe degradation (such as severe swelling) resulting in sufficient loss of integrity to make use of the elastomer unacceptable for even a short period of time.

Fair - Use of the elastomer is marginal. Use may be considered for short exposures at lower temperatures and in situations where appreciable loss of mechanical properties is not critical.

Good - Use of the elastomer is acceptable in room temperature exposure to the specific reagent. Long-term exposures may result in minor loss of properties, but exposures at elevated temperatures may result in significant property loss.

Excellent - Use of the elastomer is unaffected by the reagent. Performance of the elastomer compares well with unexposed material in regard to time, temperature and stress.

Table 6-5. Effect of elastomers on metals and water[a,b]

ELASTOMER	ALUMINUM (with water)	BRASS (with steel and water)	STEEL (with brass and water)	WATER QUALITY (with brass and steel)
EPDM	3	-	-	
EPDM	3	4	5	slight rust color
EPDM	2	3	3	slightly cloudy
EPDM	2	3	3	slight sediment
EPDM	3	3	4	clear
EPDM	2	4	5	clear
EPDM	2	4	1	clear
EPDM (high resilience)	-	4	3	sediment
Neoprene/CR	4	3	1	clear
Silicone/VMQ	1	2	6	rust and sediment
Silicone/VMQ	3	3	6	rust and sediment
Silicone/VMQ	6	2	6	rust and sediment

[a] Data from Stiehler, R. D. and J. L. Michalak. 1979. Solar energy systems-standards for rubber hose. NBSIR 79-1917. National Bureau of Standards, Washington, DC.

[b] Short lengths of elastomeric hose were stopped with metal plugs, filled 80% with water, and heated at 212°F for 166 hours.

1 = clean or nearly clean
2 = very slight discoloration
3 = slight discoloration
4 = dark discoloration
5 = slight corrosion
6 = corrosion

Absorber Materials Performance

During normal operation, the absorber coating may be in contact with the absorber plate, seals and sealants, collector housing, and insulation. It may be exposed to high humidity, high temperature and outgassing from other system materials. During abnormal conditions, the coating may come in contact with the heat transfer fluid or the glazing.

Absorber coating performance may deteriorate due to loss of adhesion, change in composition, diffusion between coating layers, or changes in optical properties (Melamed and Kaplan 1977). Discoloration, peeling, and cracking of absorber paint have resulted from high stagnation temperatures (Cash 1978).

Resistances to degradation by moisture, UV radiation, elevated temperatures, thermal cycling, thermal shock, outgassing products from other system materials, and ambient air constituents are important for long term stability of the absorber coating and efficient collector operation. Upper temperature limits are presented in Tables 8-6 and 8-7. Data for other properties are limited. Degradation of selective coatings under conditions of high humidity (Table 8-8) has indicated the importance of the underlying substrate on the coating stability. Nickel sulfamate oxide did not degrade during 18 months exposure at 100% humidity (Krupnick et al 1978). Optical properties of black copper and suflamate nickel oxide were unchanged after short exposures to UV radiation (Mattox and Sowell 1974, Krupnick et al 1978). Little degradation occurred in the durability and thermal stability of black chrome during 5 years of natural weathering, but optical peoperties did change in less than a year (Beatty and Raghunathan 1978).

Outgassing from the coating should be minimal to avoid detrimental effects to other parts of the system. Outgassing from absorber coating has resulted in fogging of glazing (U.S. Department of Housing and Urban Development 1978). Absorber paints should be thoroughly dry before glazing is installed.

Degradation by humidity of iron oxide on iron and black chrome on steel has been greatly reduced by application of organic overcoats (Mar 1978).

Table 8-6. Upper temperature limits for nonselective absorber coatings

COATING	TEMPERATURE LIMIT (°F)	REFERENCE
Anodized aluminum	500	Krupnick (1978)
Black paint	350	Krupnick (1978)
Black paint	Continuous 300	Decorative Products Division (1973)
Black paint	400	Chamberlain Manufacturing Corporation (1976)
Urethane resin over epoxy primer	300	De Soto, Inc. (1977)

Table 8-8. Humidity degradation of selective absorber coatings[a]

COATING	SUBSTRATE	HUMIDITY DEGRADATION[b]
Black nickel on nickel	Steel, copper, aluminum	Variable
Black chrome on nickel	Steel, copper, aluminum	No effect
Black chrome	Steel	Completely rusted
Black chrome	Copper	Little effect
Black chrome	Galvanized steel	Complete removal
Black copper	Copper	Complete removal
Iron oxide	Iron	Rust pinholes
Organic overcoat on iron oxide	Iron	Little effect
Organic overcoat on black chrome	Steel	Little effect

[a] Adapted from Mar, H.Y.B. 1978. Selective black paints have potential advantages. Solar Engineering, August 1978:31.

[b] Samples were exposed to high humidity for 10 days.

Table 8-7. Upper temperature limits for selective absorber coatings

COATING	TEMPERATURE LIMIT (°F)	REFERENCE
Aluminum oxide and molybdenum dioxide	1100	Melamed and Kaplan (1977)
Black chrome	570 to 660	Mar (1978)
Black chrome	350	Krupnick et al (1978)
Black copper	570	Mar (1978)
Black nickel	530	Mar (1978)
Copper sulfide		
Iron oxide	660	Mar (1978)
Lead oxide		
Lead sulfide in silicone binder		
Stainless steel oxide	800	Krupnick (1978)
Selective paint		
Sulfamate nickel oxide	700	Krupnick (1978)

REFERENCES

Ametek, Inc. 1978. Ametek new solar collector. Advertising brochure. Ametek Power Systems Group. Hatfield, PA.

Anaconda American Brass Company. 1967. Pipe tube and fittings. Publication B-1. 26th edition. Anaconda American Brass Company, Waterbury, CT.

Beatty, C.C. and K. Raghunathan. 1978. Black chrome gains favor as selective coating. Solar Engineering, August 1978: 32-33.

Cash, M. 1978. Hardware problems encountered in solar heating and cooling systems. DOE/NASA TM-78172. Technical Memorandum. (Available from NTIS, Springfield, VA.)

Chamberlain Manufacturing Corporation. 1976. Technical data on the Chamberlain Manufacturing Corporation flat plate solar collector. Chamberlain Manufacturing Corporation, Elmhurst, IL.

Decorative Products Division. 1973. Nextel brand velvet coating series 101. Product Bulletin 201. 3-M Company, St. Paul, MN.

DeSoto, Inc. 1977. Enersorb A, Super Koropon Primer. Technical data report, performance and durability testing. DeSoto, Inc., Des Plaines, IL.

Gore, E. and A.S. Quershi. 1977. Design guidelines for solar energy systems. Heating/Piping/Air Conditioning, 49(7): 43-53.

Krupnick, A.C., M.L. Roberts, and M.H. Sharpe. 1978. Natural-oxide solar-collector coatings. Technical support package. Brief No. MFS-23518. National Aeronautics and Space Administration, Marshall Space Flight Center, AL.

Mar, H.Y.B. 1978. Selective black paints have potential advantages. Solar Engineering, August 1978: 31.

Mattox, D.M. and R.R. Sowell. 1974. High absorptivity solar absorbing coatings. Journal of Vacuum Science Technology, 11(4): 793-796.

Melamed, L. and G.M. Kaplan. 1977. Survey of selective absorber coatings for solar energy technology. Journal of Energy, 1: 100-107.

PPG Industries. 1976. PPG standard solar collector general information. PPG Industries, Inc., Pittsburgh, PA.

Perry, J.H. 1975. Solar Energy for Heating and Cooling of Buildings. Noyes Data Corporation, Park Ridge, NJ.

Sax, N.I. 1979. Dangerous Properties of Industrial Materials. 5th Edition. Van Nostrand Reinhold Company, NY.

U.S. Department of Housing and Urban Development. 1978. Building the solar home. HUD-PDR-296-1. (Available From U.S. Government Printing Office, Washington, DC.)

Weast, R.C. (Editor) 1975. Handbook of Chemistry and Physics. 56th Edition. CRC Press, Inc., Cleveland, OH.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

INSULATION

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

INSULATION

Today, a high level of comfort is obtainable in our homes and other buildings, through the use of modern insulating materials. The successful operation of heating and air conditioning systems depends to a considerable extent on carefully constructed floors, walls, and ceilings where adequate consideration has been given to thermal insulation and vapor barriers. Insulation is essential in comfort-conditioned buildings--whether they are located in northern climates, or in the warm southern regions.

Economical operation, another basic objective, can be achieved through a well-insulated structure. In cold climates, fuel will be saved. When summer heat is the predominate factor, insulation will reduce the size requirements of the air conditioning equipment and also reduce the cost of operation.

A wide range of insulation materials is available to fill the requirements of modern construction. They are "engineered" for efficient installation and come in conveniently sized packages that are easy to handle and store.

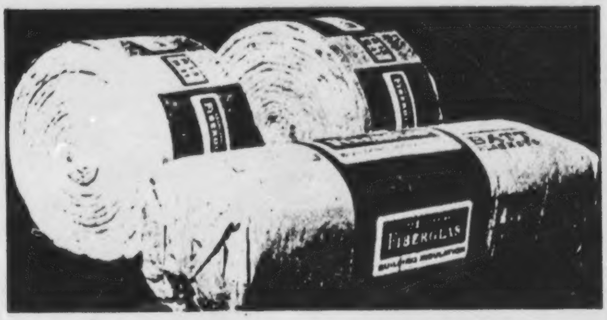


Fig. 13-1. Modern insulation materials are packaged to insure convenient handling and storage.

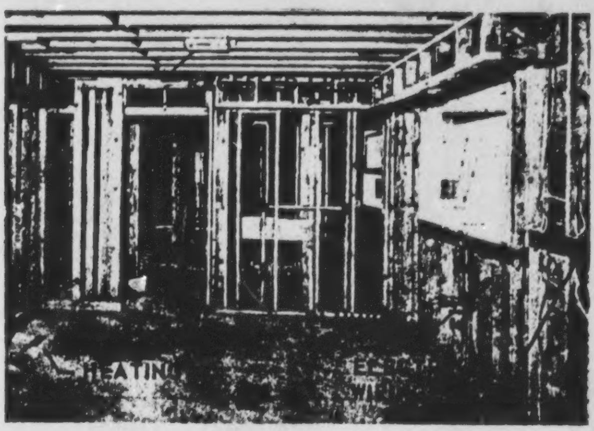


Fig. 13-4. Interior view of a residential structure with electrical, plumbing, and heating rough-in complete and ready for insulation materials.

During the installation of the heating and plumbing "rough-in", the tradesman often needs to cut through structural framework. The **carpenter** should check this work. Framing members should be reinforced wherever necessary. The figure on the next page shows an interior view of a house with the rough-in of heating, plumbing and electrical work completed and the structure ready for insulation and interior wall finish.

How Heat is Transmitted

Heat seeks a balance with surrounding areas. When the inside temperature is controlled within a given comfort range there will be some flow of heat; from the inside to the outside in winter and from the outside to the inside during hot summer weather.

Heat is transferred through walls, floors, ceilings, windows, and doors at a rate directly related to the difference in temperature, and the resistance to heat flow provided by intervening materials. The transfer of heat takes place by one or more of three methods -- conduction, convection and radiation.

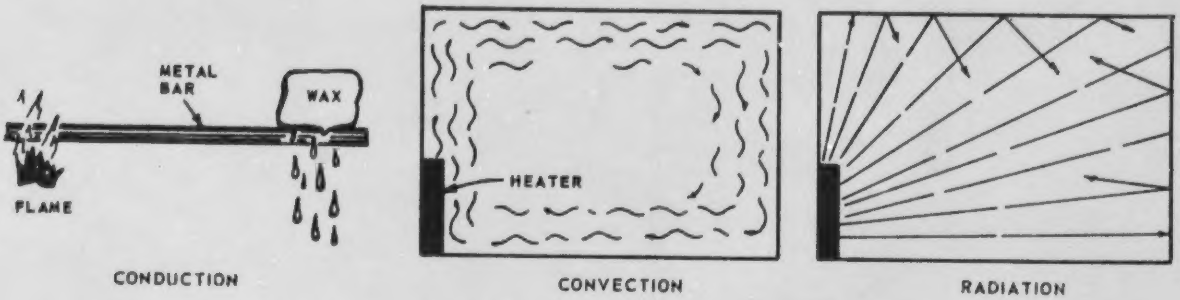


Fig. 13-5. How heat is transferred.

Conduction. Transmission of heat from one molecule to another within a given material or from one material to another when they are held in direct contact. Dense materials, such as metal or stone, conduct heat more rapidly than porous materials such as wood and fiber products. Any material will conduct some heat when a temperature difference exists between its surfaces.

Convection. This term applies to the transfer of heat by another agent, usually air. In large spaces, the molecules of air can carry heat from warm surfaces to cold surfaces. When air is heated it becomes lighter and rises, thus causing a flow of air (called convection currents) within the space. Air is a good insulator when confined to a small space or cavity where convection flow is limited or nonexistent. In walls and ceilings, air spaces are considered restrictive to convection currents and will reduce the flow of heat.

Radiation. Heat can be transmitted by wave motion in about the same manner as light. This process is called radiation because it represents radiant energy. Heat obtained from the sun is radiant heat. The waves do not heat the space through which they move, but when they come in contact with a colder surface, a part of the energy is absorbed while some may be reflected. Effective resistance to radiation is attained through reflection. Shiny surfaces, such as aluminum foil, are often used to provide this type of insulation.

Actually, heat transmission through walls, ceilings, and floors will be a result of all three of the methods, operating in various degrees. In addition to this -- some heat is lost through cracks around doors, windows, and other other openings.

Thermal Insulation

All building materials resist the flow of heat (mainly conduction) to some degree, depending on their porosity or density. As previously stated, air is an excellent insulator when confined to the tiny spaces or cells inside a porous material. Dense material such as masonry or glass contain few if any air spaces and are poor insulators. Fibrous materials are generally good insulators not only because of the porosity in the fibers themselves, but also because of the thin film of air that surround each individual fiber.

Commercial insulation materials are made of glass fibers, glass foam, mineral fibers, organic fibers, and foamed plastic. A good insulation material should be fireproof, vermin-proof, moisture proof and resistant to any physical change that would reduce its effectiveness against heat flow.

Selection must be based on initial cost, effectiveness, durability and the adaptation of its form to that of the construction and installation methods.

Heat Loss Coefficients

The thermal properties of common building materials and insulation materials are known or can be accurately measured. The amount of heat flow (transmission) through any combination of these materials can be calculated. First it is necessary to know and understand certain terms.

Btu - The abbreviation for British thermal unit and is the amount of heat needed to raise the temperature of 1 lb. of water 1 degr. F.

k - The amount of heat (in Btu's) transferred in one hour through 1 square foot of a given material that is 1 in. thick and has a temperature difference between its surfaces of 1 deg. F. It is also called the coefficient of thermal conductivity.

C - Represents the conductance of a material (regardless of its thickness) and shows the amount of heat (Btu's) that will flow through the material in one hour per square foot of surface with 1 deg. temperature difference. Example: the C value for an average hollow concrete block is .53.

R - Represents the resistivity or resistance which is the reciprocal of conductivity or conductance. A good insulation material will have a high R value.

$$R = \frac{1}{k} \text{ or } \frac{1}{C}$$

U - Represents the total heat transmission (Btu's) per square foot, per hour with 1 deg. temperature difference for a structure (wall, ceiling, floor) which may consist of several materials or spaces. A standard frame wall with composition sheathing, gypsum lath and plaster, with a 1 in. blanket insulation will have a U value of about .11. To calculate the U value where the R values are known, apply the following formula:

$$U = \frac{1}{R_1 + R_2 + R_3}$$

The figure below shows how insulation reduces the U value for a conventional frame wall. Note that the 3 1/2in thick blanket reduces the U value from .29 to .07 (about a 75 percent reduction). Actually the U value for the total wall structure will be slightly higher because the wood studs have a lower R value than the blanket insulation.

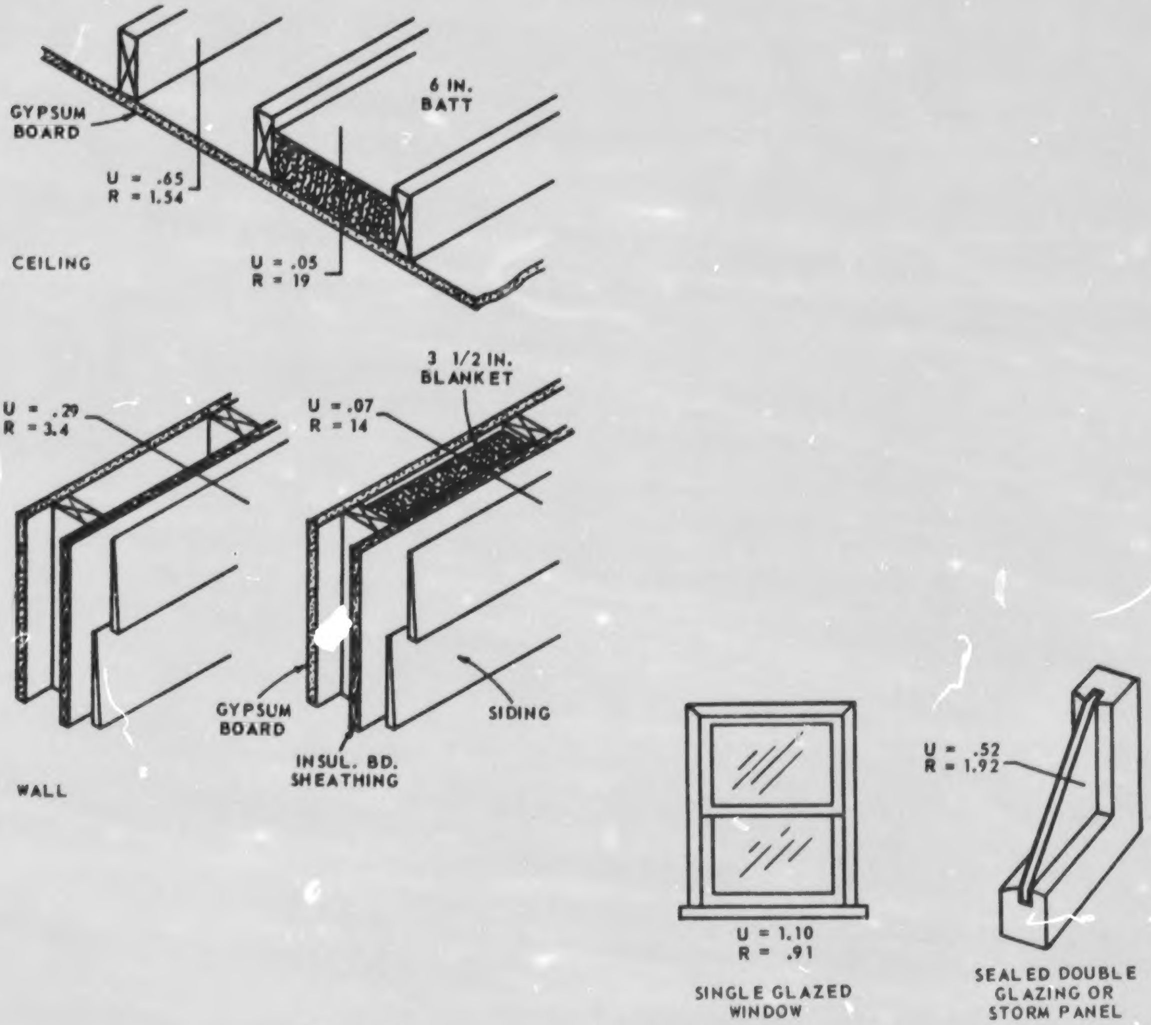

GYPSUM BOARD
6 IN. BATT
U = .65
R = 1.54
CEILING
U = .05
R = 19
3 1/2 IN. BLANKET
U = .29
R = 3.4
U = .07
R = 14
GYPSUM BOARD
SIDING
INSUL. BD. SHEATHING
WALL
U = .52
R = 1.92
U = 1.10
R = .91
SINGLE GLAZED WINDOW
SEALED DOUBLE GLAZING OR STORM PANEL

Fig. 13-6. How insulation reduces flow of heat. Air space serves as insulation in double-glazing.

The original source of most data on this subject is the American Society of Heating, Refrigerating, and Air Conditioning Engineers Guide and Data Book (ASHRAE). The U values listed on the following charts can be converted to R values by finding the reciprocal (dividing the value into 1).

"U" VALUES OF COMMON WALL CONSTRUCTION — ⅜" GYPSUM LATH AND ½" PLASTER INTERIOR

TYPE OF WALL*	Construction Indicated	WITH INSULATION BETWEEN FRAMING (gypsum lath and plaster interior)						
		1" Batt or Blanket	2" Batt or Blanket	3" Batt or Blanket	3⅝" Wool Loose Fill	Reflective Insulation E = 0.0		
						1 Air Space	2 Air Spaces	3 Air Spaces
FRAME — Wood siding or wood shingle								
1. With wood sheathing	0.24	0.13	0.087	0.065	0.065	0.17	0.12	0.079
2. With ½" reg. density insulation board sheathing	0.23	0.12	0.086	0.065	0.065	0.17	0.11	0.078
3. With $^{25}/_{32}$" insulation board sheathing	0.19	0.11	0.080	0.061	0.061	0.14	0.10	0.071
4. With shingle backer, wood shingles and $^{25}/_{32}$" insulation board sheathing	0.18	0.11	0.078	0.060	0.060	0.14	0.10	0.069
VENEER — Brick on Frame								
1. With wood sheathing	0.27	0.14	0.090	0.067	0.067	0.19	0.12	0.083
2. With ½" reg. density insulation board sheathing	0.25	0.13	0.088	0.066	0.066	0.18	0.12	0.081
3. With $^{25}/_{32}$" insulation board sheathing	0.21	0.12	0.083	0.063	0.063	0.16	0.11	0.075
8" CINDER BLOCK	0.25	0.13	0.088	0.066	0.066	0.18	0.12	0.081
8" SOLID BRICK (Face and Common)	0.29	0.14	0.092	0.069	0.069	0.20	0.13	0.086

"U" VALUES OF COMMON FRAME CEILINGS

Heat Flow Up

TYPE OF CEILING*	INSULATION BETWEEN OR ON TOP OF JOISTS (No Flooring Above)										
	None	Regular Density Insulation Board on top of joists		Blanket or Batt insulation between joists			Perlite or Vermiculite between joists		Reflective Insulation E = 0.05		
		½"	1"	1"	2"	3"	2"	4"	1 Air Space	2 Air Spaces	3 Air Spaces
No Ceiling		0.38	0.24								
Gypsum Board (⅜")	0.65	0.26	0.19	0.19	0.11	0.079	0.18	0.11	0.38	0.21	0.14
Gypsum Lath (⅜") Plastered	0.61	0.26	0.19	0.19	0.11	0.078	0.17	0.10	0.37	0.21	0.14
Plywood (⅜")	0.59	0.25	0.18	0.18	0.11	0.078	0.17	0.10	0.36	0.20	0.14
Insulation Board (½" Regular Density)	0.38	0.20	0.16	0.16	0.10	0.074	0.15	0.09	0.26	0.17	0.12

"U" VALUES OF COMMON FRAME FLOORS

Heat Flow Down

TYPE OF FLOOR*	INSULATION BETWEEN OR ON BOTTOM OF JOISTS								
	None	Regular Density Insulation Board on bottom of joists		Blanket or Batt insulation between joists			Reflective Insulation E=0.05		
							1 Air Space	2 Air Spaces	3 Air Spaces
		½"	1"	1"	2"	3"	Heat Flow Down		
Single Wood	0.35	0.18	0.14	0.13	0.087	0.066	0.096	0.052	0.040
Double Wood	0.28	0.16	0.13	0.12	0.082	0.063	0.089	0.050	0.039

*Refer to ASHRAE Guide and Data Book for reference to these and other roof and floor assemblies.

Fig. 13-7. "U" values for various constructions commonly used in residential building.

Basic wall construction*		Interior finish			
		Plain wall no plaster	½-in. plaster on:		
			Wall direct	¾-in. furring with:	
				⅜-in. plasterboard	½-in. rigid insulation
Concrete masonry (cores not filled)	8-in. sand and gravel or limestone	0.53	0.49	0.31	0.22
	8-in. cinder	0.37	0.35	0.25	0.19
	8-in. expanded slag, clay or shale	0.33	0.32	0.23	0.18
	12-in. sand and gravel or limestone	0.49	0.45	0.30	0.22
	12-in. cinder	0.35	0.33	0.24	0.18
	12-in. expanded slag, clay or shale	0.32	0.31	0.23	0.18
Concrete masonry (cores filled with insulation)**	8-in. sand and gravel or limestone	0.39	0.37	0.26	0.19
	8-in. cinder	0.20	0.19	0.16	0.13
	8-in. expanded slag, clay or shale	0.17	0.17	0.14	0.12
	12-in. sand and gravel or limestone	0.34	0.32	0.24	0.18
	12-in. cinder	0.20	0.19	0.15	0.13
	12-in. expanded slag, clay or shale	0.15	0.14	0.12	0.11
4-in. face brick plus:	4-in. sand and gravel or limestone unit	0.53	0.49	0.31	0.23
	4-in. cinder, expanded slag, clay or shale unit	0.44	0.42	0.28	0.21
	4-in. common brick	0.50	0.46	0.30	0.22
	8-in. sand and gravel or limestone unit	0.44	0.41	0.28	0.21
	8-in. cinder, expanded slag, clay or shale unit	0.31	0.30	0.22	0.17
	8-in. common brick	0.36	0.34	0.24	0.19
	1-in. wood sheathing, paper, 2x4 studs, wood lath and plaster	—	0.27	0.27	0.20

*All concrete masonry shown in this table are hollow units All concrete masonry wall surfaces exposed to the weather have two coats of portland cement base paint. Surfaces of all walls exposed to the weather subject to a wind velocity of 15 miles per hour.

**Values based on dry insulation. The use of vapor barriers or other precautions must be considered to keep insulation dry.

Fig. 13-8. U values for various masonry walls used in residential and commercial buildings. (Portland Cement Assoc.)

How Much Insulation

Comfort and health in a dwelling during cold weather depend not only on the air temperature of the heated space, but also on the temperatures of the room surfaces. It is quite possible to maintain a satisfactory level of air temperature with extra heat and still have cold walls and floors. The human body will lose heat by radiation (or conduction if in contact) to these colder surfaces. Minimizing the difference in temperature between inclosed surfaces and room air can be achieved by adding insulating materials that will reduce the loss of heat through these surfaces.

The figures below suggest amounts of insulation for three comfort levels by listing U and R values. These amounts may be related generally to climate zones throughout the country. In the lower belts, minimum amounts of insulation are needed to provide comfort during the heating season. For some of these areas it will be more important to base the amount of insulation on requirements for economical operation of cooling equipment.

Rising costs of energy, coupled with anticipated shortages, have emphasized the importance of insulation. Today, the amount of insulation for a given structure must be based not only on comfort standards, but also on such factors as insulation costs (material and labor), projected fuel prices, and local climatic conditions. These factors are covered in a booklet, "Thermal Performance Guidelines", published by the National Association of Home Builders, (NAHB). One part provides a listing of R values based on climatic conditions. For example, an R-18 value is recommended for exterior walls in a locality such as Minneapolis, Minnesota which has a winter design temperature of -14 deg. F. and 8400 degree days.

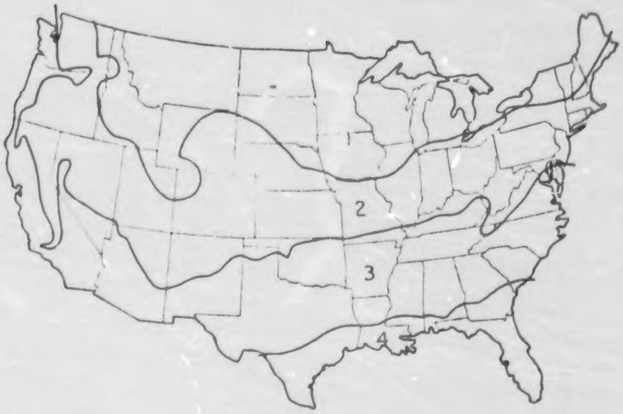


Fig. 13-10. U. S. Department of Agriculture climate zones.

ALL-WEATHER COMFORT STANDARD

	U-VALUE	INSULATION "R" NUMBER
Ceilings	0.05	R19
Walls	0.07	R11
Floors Over Unheated Spaces	0.07	R13

MODERATE COMFORT AND ECONOMY STANDARD

	U-VALUE	INSULATION "R" NUMBER
Ceilings	0.07	R13
Walls	0.09	R8
Floors Over Unheated Spaces	0.09	R9

MINIMUM COMFORT STANDARD

	U-VALUE	INSULATION "R" NUMBER
Ceilings	0.10	R9
Walls	0.11	R7
Floors Over Unheated Spaces	0.11	R7

Fig. 13-9. U values and comfort standards. (National Forest Products Assoc.)

A DEGREE DAY IS THE PRODUCT OF ONE DAY AND THE NUMBER OF DEGREES F. THE MEAN TEMPERATURE IS BELOW 65 F. FIGURES ARE USUALLY QUOTED FOR A FULL YEAR AND ARE USED BY THE HEATING ENGINEER TO DETERMINE THE DESIGN AND SIZE OF THE HEATING SYSTEM.

R-18 plus values in residential wall construction can be obtained by using 2 x 6 studs which provide a thicker wall cavity for insulation. Another system uses 2 x 4 studs sheathed with thick, rigid insulation panels made from foamed plastic.

From a study of tables listing U and R values it will be noted that heat transmission decreases as the insulation thickness increases, but not in a direct relationship. The first inch reduces the U value more (proportionally) that the second inch. For example in a frame wall with a U value of .24 the addition of 1 in. of insulation will reduce the value by 46 percent to .13; the second inch will reduce it by 16 percent to .09; and the third inch by 10 percent to .065. Additional thickness will continue to lower the U value, but at a still lower percentage. Thus, at some point, it becomes useless to add more insulation.

Types of Insulation

Insulation is made in a variety of forms and types and may be grouped into four broad classifications; 1) Flexible, 2) Loose fill, 3) Rigid, 4) Reflective.

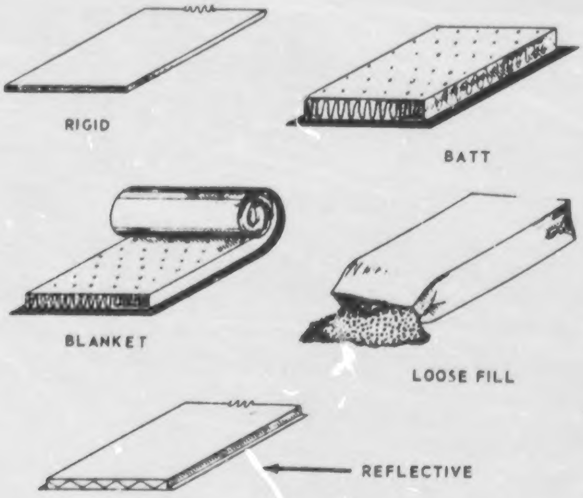


Fig. 13-11. Basic forms of insulation.

Flexible insulation is manufactured in two types: Blanket or quilt, and batt. Blanket insulation is generally furnished in rolls or strips of convenient length and in various widths suited to standard stud and joist spacing. It comes in thicknesses of 1 to 3 1/2 inches. See figure on next page.

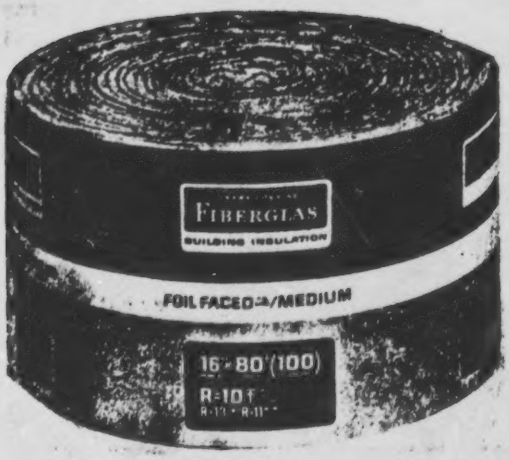


Fig. 13-12. A roll of blanket insulation, 15 in. wide, to fit between studs 16 in. O.C. The thermal resistance to heat flow R varies for floor, wall, or ceiling installation. Note the arrows indicating the direction of heat flow and R value.

The body of the blanket is made of loosely felted mats of mineral or vegetable fibers, such as rock, slag, glass wool, wood fiber, and cotton. Organic fiber mats are usually treated chemically to make them resistant to fire, decay, insects, and vermin. Blanket insulation is usually enclosed in paper covers with tabs on the side for attachment. The covering sheet on one side may be treated to serve as a vapor barrier. In some cases the covering sheet is surfaced with aluminum foil or other reflective insulation.

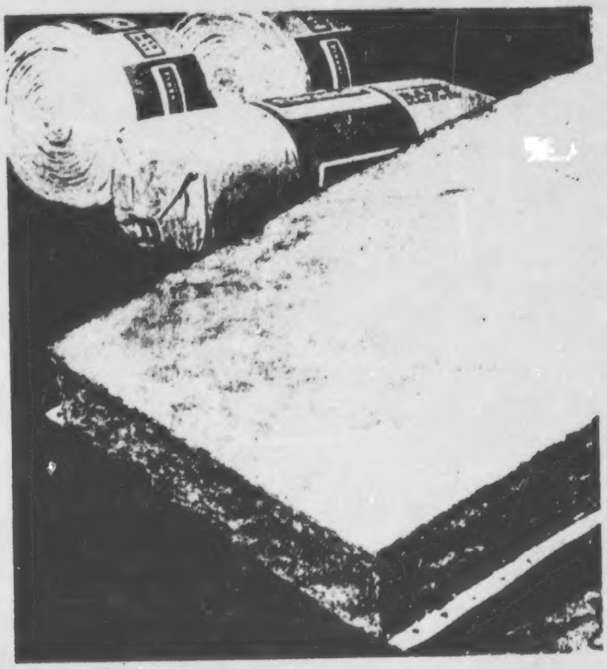


Fig. 13-13. Standard blanket insulation. Note flange along the lower edge used to attach blanket to joists and studs. (Owens-Corning Fiberglas Corp.)

Batt insulation is made of the same fibrous material as blankets. Thickness can be greater in this form and may range from 2 in. to 6 in. They are generally available in widths of 15 and 23 in. and in 24 and 48 in. lengths. Batts are available with a single flanged cover or with both sides covered as shown below.

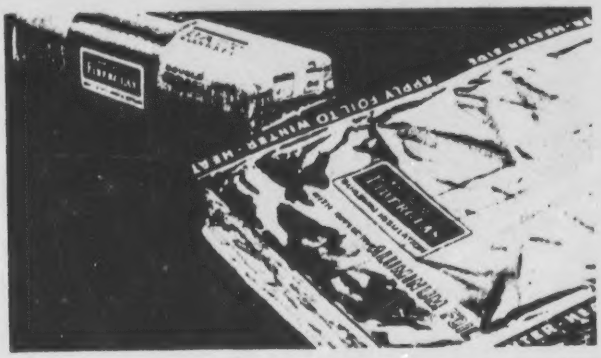


Fig. 13-14. Batt with aluminum foil cover. Opposite side has a porous foil breather paper.

Loose fill insulation is composed of various materials used in bulk form and supplied in bags or bales. It may be poured, blown, or placed by hand and is commonly used to fill spaces between studs or to build up any desired thickness on a horizontal surface.

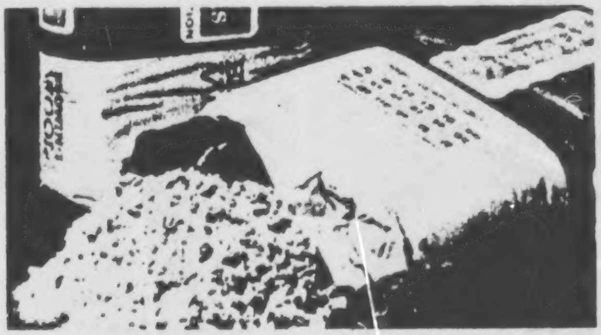


Fig. 13-15. Loose fill insulation. Each bag covers a nominal 25 square feet to a depth of 4 inches.

Loose fill insulation is made from such materials as rock, glass, slag wool, wood fibers, shredded redwood bark, granulated cork, ground or macerated wood pulp products, vermiculite, perlite, powdered gypsum, sawdust and wood shavings. One of the chief advantages of this type is that when insulating an older structure only a few boards need to be removed in order to blow the material into the walls.

Rigid insulation as ordinarily used in residential construction, is made by reducing wood, cane, or other fiber to a pulp and then assembling the pulp into lightweight or low-density boards that combine strength with heat and acoustical insulating properties.

It is available in a wide range of sizes, from tile 8 in. square, to sheets 4 ft. wide and 10 ft. or more long. Insulating boards are usually 1/2 in. to 1 in. in thickness. Boards of greater thickness are made by laminating together boards of standard thickness.

C or K values for individual materials are not directly applicable to heat loss calculations. Instead they must first be converted into a resistance value R. Engineering handbooks will list R values for a wide range of specific items. The chart below lists an accepted general value for some commonly used materials.

MATERIAL	THICKNESS	R
Brick Veneer	4 IN.	.44
Concrete Block	8 IN.	1.11
Hardboard	1/4 IN.	.18
Plywood	3/8 IN.	.47
Insulation Board	25/32 IN.	2.06
Gypsum Sheathing	1/2 IN.	.45
Wood	25/32 IN.	.98
Gypsum Lath and Plaster	7/8 IN.	.41
Mineral Wool Blanket	1 IN.	3.70
Plastic (Foamed)	1 IN.	5.00
Corkboard	1 IN	3.70
Vermiculite (Loose Fill)	1 IN.	2.08
Air Space (Vertical)	3/4 IN. OR MORE	.97

Fig. 13-16. R values for common construction and insulation materials.

Insulating boards are used for many purposes including roof and wall sheathing; subflooring; interior surface of walls and ceilings; base for plaster; and insulation strips for foundation walls and slab floors.

Although somewhat expensive, foamed glass or cork board makes an excellent rigid form of insulation. A recent development that is widely used today is foamed plastic (polystyrene). Because of its water-resistant quality it is especially adaptable to masonry work.

Insulating boards should not be confused with ordinary wallboard, which is more tightly compressed and has less insulating value. Insulating sheathing board ordinarily comes in two thicknesses, 1/2 and 25/32 in. They are available in 2 x 8 ft. sheets for horizontal application, and 4 x 8 sheets or longer for vertical application.

Reflective Insulation

Reflective insulation, which is usually a metal foil, or foil-surfaced material, differs from other insulating materials in that the number of reflecting surfaces, not the thickness of the material, determines its insulating value. In order to be effective, the metal foil must be exposed to an air space, preferably 3/4 in. or more in depth.

Aluminum foil is available in sheets or corrugations supported on paper. It is often mounted on the back of gypsum lath. One of the most effective forms of reflective insulation is multiple spacecd sheets as shown below.

Fig. 13-17. Installing reflective insulation.
(Bostitch, Inc.)

Other Types of Insulation

There are available on the market today many insulations which do not fit the classifications covered previously in this section. Some examples include the confetti like material mixed with ashesive and sprayed on the surface to be insulated; multiple layers of corrugated paper; and lightweight aggregates like vermiculite and perlite used in plaster to reduce heat transmission. Lightweight aggregates made from blast furnace slag, burned clay products, and cinders are commonly used in concrete and concrete blocks to improve the insulation qualities of these materials.

Functional Properties

Insulation is a solid that contains gas-filled spaces. These spaces may be enclosed within the solid much like trapped bubbles or may exist between small particles or fibers which make up the insulation. Gases are inefficient at transferring heat when they are confined to such small spaces and provide a means of restricting heat flow. The ease of heat flow through a material is indicated by the thermal conductivity. The lower the thermal conductivity, the better the insulation. Thermal conductivity is the quantity of energy transferred in one hour across a specific area of insulation of a given thickness when a 1°F temperature difference exists across the insulation. Thermal conductivity changes with temperature; thus, a comparison of insulations should be made at a given temperature, preferably the temperature at which the insulation will be operating. Thermal conductivities of insulations are presented in Table 5-1.

Table 5-1. Thermal conductivities and upper temperature limits of insulations[a]

INSULATION	THERMAL CONDUCTIVITY (Btu-in/ft^2/h/°F)	UPPER TEMPERATURE LIMIT (°F)
Calcium silicate	0.38 at 200°F	1200
Mineral fiber block	0.25 at 75°F	1900
Mineral fiber board	0.38 at 75°F	1200
Perlite	0.48 at 200°F	1500
Refractory fiber board	0.30 at 200°F	1200
Glass fiber board	0.22 at 75°F	650
Cellular elastomer	0.25 at 75°F	220
Polystyrene	0.20 to 0.27 at 75°F	165
Polyurethane	0.16 at 75°F	220
Isocyanurate	0.17 at 75°F	250
Phenolic	0.23 at 75°F	275
Urea formaldehyde	0.22 at 70°F	270
Cellulose	0.27 to 0.35	

[a] Data from Anderson and Wilkes (1977); Dow Chemical U.S.A.; Gilleland (1980) MICA (1979); National Foam Products, Inc.; Schutz (1968); U.S. Mineral Products Co.; and Armstrong (1979).

Operational Considerations

During normal operation of active systems, insulation may be in contact with common building materials such as metal, wood, and plastic; specifically, the plumbing, collector plate, collector housing, and wall of the thermal storage tank. Temperatures may reach 400°F at the collector plate and plumbing surface, and 200°F at the storage tank wall. Humidity may be high in the collector. If water is used for thermal storage, tank insulation may be exposed to high humidity and steam. Collector and plumbing insulation may be exposed to UV radiation. Under abnormal conditions, the insulation may also come in contact with thermal storage media and heat transfer fluid. The following paragraphs discuss mechanical and chemical properties that should be considered in determining whether a specific insulation is suitable for a specific purpose.

The upper temperature limit of insulation (Table 5-1) is critical in solar heating systems. Possible methods of preventing insulation from reaching the upper limit when used in high temperature areas are (s) separating insulation from the absorber plate by an air space and covering the insulation with reflective foil and (b) using composite insulations, in which efficient foam insulations that degrade at relatively low temperatures are shielded from hot surfaces with high-temperature inorganic insulations, such as glass fiber.

OUTGASSING OF VOLATILE COMPOUNDS FROM INSULATION IS A COMMON PHENOMENON AT HIGH TEMPERATURES. OUTGASSING IS OFTEN QUANTIFIED BY LOSS OF WEIGHT OF A SAMPLE WHEN EXPOSED TO HIGH TEMPERATURES. WEIGHT LOSS AND, HENCE, OUTGASSING OCCUR AT TEMPERATURES BELOW MANUFACTURERS' RECOMMENDED MAXIMUM USE TEMPERATURES (Table 5-2). THE CONDENSATION OF THE OUTGASSING PRODUCTS ON THE GLAZING CAN REDUCE SOLAR TRANSMISSION AND, THEREBY, COLLECTOR EFFICIENCY.

Outgassing compounds from foam insulations include the blowing agents and products of thermal degradation (Table 5-3). Outgassing products are also derived from organic binders used with glass fiber. The loss of blowing agent from foam reduces the insulation value. The loss of organic binder from glass fiber causes reduction in resiliency.

Table 5-2. Outgassing properties of insulation

INSULATION	ONSET OF WEIGHT LOSS[a] (°F)	MANUFACTURER'S RECOMMENDED UPPER LIMIT[a] (°F)	WEIGHT LOSS AT 325°F[b] (% of original weight)
Glass fiber building insulation	302		
Glass fiber high density board	212	450	
Glass fiber with low binder content	302	1000	
Glass fiber with no binder	482	1000	
Polystyrene			1
Polyurethane			4 to 6.5
Isocyanurate	122	250	7
Urea formaldehyde			6.5

[a] Data from Gilleland, F. W. 1980. Insulation for solar collectors important to heat loss control. Solar Engineering, January 1980: 20-21.

[b] Data from Stahl, J. A. 1978. Using foam plastic insulation safely. Fire Journal, September 1978: 43-47+.

Table 5-3. Outgassing products from insulation

INSULATION	OUTGASSING PRODUCTS
Polystyrene[a]	Styrene Methylstyrene
Isocyanurate[a]	Carbon dioxide Hydrogen chloride Trichlorofluoromethane
Polyurethane[a]	Carbon dioxide Hydrogen chloride Trichlorofluoromethane Chloroethyl phosphate
Urea formaldehyde[b]	Formaldehyde
Class fiber[a]	Carbon dioxide Saturated alkanes

[a] Outgassing products at 400°F in high vacuum determined by mass spectroscopy, Sandia Laboratories, Albuquerque, NM.

[b] Data from Allan, G.G., J. Dutkiewicz, and E.J. Gilmartin. 1980. Long-term stability of urea-formaldehyde foam insulation. Environmental Science and Technology, 14:1235-1240.

Fire Hazards

Fire properties of insulation are presented in Tables 5-6, 5-7, 5-8 and 5-9. The data for the plastic foams should be used with caution inasmuch as the general understanding of the burning of plastics is limited. Fire protection research of plastic foams has indicated that the specific formulation greatly affects fire behavior and that interpretation of expected fire behavior based on usual small-scale tests is unreliable (Betz 1978, Factory Mutual Research Corporation 1974, 1975). ASTM E-84 test results are presented here for completeness. However, because the test does not adequately describe the actual flame spread performance of foam plastics, the Federal Trade Commission requires all manufacturers of foam plastic raw materials to make the following statement when ASTM E-84 flame spread ratings are presented: "This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions" (Stahl 1978).

Calcium silicate, mineral fiber, perlite foam, and refractory fiber are noncombustible. Glass fiber itself is concombustible, but the organic binders used in the production of glass fiber insulation can be hazardous by burning, smoldering, or outgassing during fires.

The following paragraphs discuss the general fire behavior of plastic foams and give specific information of the fire properties of polystyrene, polyurethane, isocyanurate and urea-formaldehyde rigid foams (compiled from Committee on Fire Safety Aspects of Polymeric Materials 1979 and other cited references).

Plastic foams react to fire in different ways depending on their chemical structures. Some rigid foams such as polystyrene usually melt or decompose into volatile compounds. Other foams such as phenolics usually char in place rather than melt or decompose.

Plastic foams have relatively low decomposition temperatures, questionable flame spread performance, large surface area, variable toxic gas generation, and high smoke emission. To reduce the potential fire hazard due to these characteristics, building codes have mandated that foam plastic insulation materials be protected with fire resistant sprinklers and/or thermal barriers (Stahl 1978), with the latter being a commonly recommended practice (Blaga 1978; Baldwin 1975). Flame spread can be reduced and ignition delayed by covering the insulation; but, generation of heat, smoke and toxic gases may occur rapidly if metal coverings, which transmit heat of the fire directly to the foam, are used (Stahl 1978). Fire-resistant thermal barriers, such as 1/2 inch gypsum board will protect foam from decomposing for at least 15 minutes at fire temperatures greater than 1000°F (Stahl 1978).

Table 5-6. Qualitative comparison of fire properties of foam insulation[a]

INSULATION	DESCRIPTION	IGNITABILITY	FLAMMABILITY	HEAT RELEASE	SMOKE
Polystyrene	Board	NA	NA	M	D
	Board Attached to Noncombustible Substrate	NA	M	L	D
	Flame Retardant Grade Attached to Noncombustible Substrate	NI	M	L	D
Polyurethane	Board	I	R	h	D
	Flame Retardant Grade	NI	L/M	M	D
Isocyanurate	Board	NI	L	M	D
Urea Formaldehyde	Board	NI	R	M	L

[a] Adapted from Malhotra, H. L. 1977. The behavior of polymers used in building construction. British JFRO.

L = Low
D = Dense
H = High
NA = Not Applicable

[illegible] = Medium
R = Rapid
I = Easily Ignitable
NI = Not Easily Ignitable.

Table 5-7. Fire properties of insulation,
ASTM E84 tunnel test

INSULATION	DESCRIPTION	FLAME SPREAD	FUEL CONTRIBUTED	SMOKE DEVELOPED	REFERENCE
Calcium Silicate	Pipe Covering, Block, Segments		Not Combustible		MICA (1979)
Mineral Fiber	Block, Board		Not Combustible		MICA (1979)
Perlite Foam	Pipe Covering, Blocks		Not Combustible		MICA (1979)
Refractory Fiber	Blanket, Pipe Covering, Board		Not Combustible		MICA (1979)
Glass Fiber	With Organic Binder	25		50	Malloy (1969)
Cellular Elastomer	Sheet, Pipe Covering	75			Johns-Manville (1978)
	Sheet	≤25		≤100 to 150	Armstrong (1979)
Polystyrene Foam	-----	25			Stahl (1978)
	-----	5 to 15	5 to 15	5 to 15	U.S. Mineral Products Co.
Polyurethane Foam	4 Types	25 to 600			Stahl (1978)
	6 Types	35 to 60	Not Determined	145 to 405	Factory Mutual (1978)
Isocyanurate Foam	-----	30			Stahl (1978)
	3 Types	20 to 25	15	75 to 105	Factory Mutual (1978)

(continued)

Table 5-7. continued

INSULATION	DESCRIPTION	FLAME SPREAD	FUEL CONTRIBUTED	SMOKE DEVELOPED	REFERENCE
Phenolic Foam	Pipe Covering	≤25		≤50	Armstrong (1979)
Urea Formaldehyde	Modified	10	0	35	Rapperswill Corp. (1976)
Urea Formaldehyde	_____	5	0	0	Factory Mutual (1978)
Cellulose	2.5 lb/ft^3	15	5	10	Rhode Island Energy Corporation (1978)
	13 Types	10 to 15	0 to 5	0 to 110	Factory Mutual (1978)
	19 Types	10 to 20			Anderson and Wilkes (1978)
Asbestos Board	For Comparison	0	0	0	Hilado (1974)
Red Oak	For Comparison	100	100	100	Hilado (1974)

Table 5-8. Flame spread of foam insulation, ASTM 162 radiant panel test[a]

INSULATION	DESCRIPTION	FLAME SPREAD
Polystyrene	Rigid	114
	Rigid flame retarded	13
Polyurethane	Flexible polyester fire retarded	1000
	Flexible polyether	1490
	Flexible polyether fire retarded	10
	Rigid polyester fire retarded	1440
	Rigid polyether	2220
	Rigid polyether fire retarded	800
Asbestos board	For comparison	0
Red oak	For comparison	99

[a] Data from Hilado, C. J. 1969. Flammability Handbook for Plastics. Technomic Publishing Co., Westport, CT.

Table 5-9. Smoke production by foam insulation, NBS chamber test[a]

INSULATION	DESCRIPTION	FLAMING	NONFLAMING	REFERENCE
Cellular Elastomer	Sheet Pipe Covering	270 to 400 (average of flaming and nonflaming)		Johns-Manville (1978)
Polystyrene	Rigid	468	460	Gaskill (1970)
	Rigid	390	25	Lee (1973)
	Rigid Flame Retarded	260	10	Hilado (1969)
Polyurethane	Flexible	20	156	Hilado (1969)
	Flexible Polyester Fire Retarded	110 to 770		Sarkos (1976)
	Flexible Polyester Fire Retarded	10	161	Gaskill (1970)
	Flexible Polyether	319	515	Gaskill (1970)
	Flexible Polyether Fire Retarded	159 to 202		Sarkos (1976)
	Flexible Polyether Fire Retarded	285	290	Gaskill (1970)
	Rigid Polyester Fire Retarded	525	454	Gaskill (1970)
	Rigid Polyether Fire Retarded	196	119	Gaskill (1970)
Isocyanurate	Fire Retarded	225	300	Gaskill (1970)
Urea Formaldehyde		16	51	Rapperswill Corp. (1976)
Red Oak	For Comparison	76	395	Hilado (1969)
Red Oak	For Comparison	200 to 250		Rapperswill Corp. (1976)

[a] Values indicate maximum densities of smoke.

Polystyrene Rigid Foam

Dense smoke and rapid burning are characteristic of the combustion of polystyrene. Carbon monoxide is a major combustion product, as it is of all carbon-containing materials (see Toxicity of Combustion and Pyrolysis Gases, which follows), but other highly toxic compounds resulting from combustion have not been identified.

Several approaches to flame retarding polystyrene can be used. Brominated carbon compounds and copper phthalocyanine are used to fire retard some polystyrene foams. Additives which induce breakdown of polymer chains, melting, and dripping when heat is applied to the foam allow retraction of the foam from the flame source.

Other approaches include addition of other halogenated compounds to the foam, incorporation of halogenated compounds into the polymer chain by chemical bonding, and addition of small amounts of free radical initiators such as peroxides to improve the efficiency of the halogens. However, these or other approaches may not be entirely adequate. Fire retarding does make ignition by small flame sources more difficult, but it does not prevent rapid flame spread and high rates of combustion in more intense fires.

The actual fire hazard posed by polystyrene foam depends on its physical and chemical properties and those of the surrounding environment. A severe fire hazard exists if polystyrene is nto protected by more fire resistant materials and thus is readily ignitable. Shape, surface area, protective coatings, additives, and chemical modifications have not been adequately studied under actual fire conditions to allow generalizations about their effects on hazard potential to be made.

The following caution is supplied by a manufacturer:

WARNING! (POLYSTYRENE) PRODUCTS ARE ORGANIC MATERIALS WHICH DECOMPOSE AT 165° AND WILL IGNITE AND BURN AT 450°F, OR WHEN EXPOSED TO OPEN FLAME. THESE PRODUCTS ARE FLAMMABLE AND MAY CONSTITUTE A FIRE HAZARD IF IMPROPERLY USED OR INSTALLED. THEY SHOULD NOT BE USED IN EXPOSED OR INADEQUATELY PROTECTED APPLICATIONS OR EXPOSED TO FLAME SOURCES DURING CONSTRUCTION. (U. S. Mineral Products Company).

Polyurethane Rigid Foam

The low thermal conductivity of polyurethane results in the rapid build up of heat at the surface when the foam is exposed to an ignition source. The resulting high surface temperature causes immediate volitization of combustible gases. These burn intensely and result in rapid surface flame spread.

Polyurethane foams are fire retarded by the use of halogen and phosphorus compounds which lead to high char formation. Commercial preparation of the foams currently employs phosphorus or phosphorus plus chlorine to reduce the tendency of the foam to burn. The wide use of these fire retardants arises not only from their fire properties, but also from the low viscosity of most phosphorus compounds which allows easy processing.

Nonreactive additives that serve as plasticizers and fillers also induce fire retardancy; tri - (2,3-dibromopropyl) phosphate is one such material. However, under long-term use, they may be expelled from the foam. Therefore, they have not been extensively employed as fire retardants.

The following caution has been supplied by a manufacturer:

WARNING! RIGID FOAMED POLYURETHANES ARE ORGANIC MATERIALS WHICH DECOMPOSE ABOVE 450° F AND WILL IGNITE AND BURN AT 600 - 700° F, OR WHEN EXPOSED TO OPEN FLAME. THESE PRODUCTS SHOULD NOT BE USED IN EXPOSED APPLICATIONS OR EXPOSED TO FLAME SOURCES DURING CONSTRUCTION. (U. S. Mineral Products Company).

Isocyanurate Rigid Foam

This foam can be formulated with fire resistant properties. It has low smoke generation, low fuel contribution, and good flame resistance.

Urea-formaldehyde Foam

Urea-formaldehyde foams have low tendency to ignite and burn. Phosphorus and boron compounds and other fire retardant additives can decrease their flammability even further.

TOXICITY OF COMBUSTION AND PYROLYSIS GASES

Many different gases are emitted during pyrolysis and combustion of foam insulation. Data for polyurethane foam with and without flame retardants under pyrolysis and combustion conditions (Table 5-10) demonstrate the effects of formulation and oxygen availability on the quantities of gases produced.

Carbon monoxide is thought to be responsible for more deaths than other gases in real fire situations. The highly toxic hydrogen cyanide is produced in various concentrations from many nitrogen-containing compounds, such as foam insulations, during pyrolysis and combustion (Einhorn 1975). With flexible polyurethane foam, carbon monoxide is the dominant contributor to gas toxicity at low temperatures, but hydrogen cyanide and carbon monoxide are of comparable importance during pyrolysis or combustion at 2000°F (Bowes 1974).

Other chemicals may also contribute significantly to gas toxicity. A highly toxic bicyclophosphate has been identified in the combustion products of a flame-retarded rigid urethane foam (Vorhees 1975). Lethal concentrations of pyrolysis and combustion gases are presented in Table 5-11.

Table 5-10. Relative abundance of identified pyrolysis and combustion products from a rigid polyurethane foam[a]

PRODUCT	PYROLYSIS		COMBUSTION	
	Not Fire Retarded	Fire Retarded	Not Fire Retarded	Fire Retarded
Carbon monoxide (+ Air)	L	L	L	L
Methane	S	L	-	Trace
Carbon dioxide	L	L	L	L
Nitrous Oxide	-	-	S	S
Ethylene	L	L	S	L
Acetylene	Trace	Trace	S	L
Ethane	L	L	Trace	S
Propylene	L	L	L	L
Water	L	L	L	L
Propyne	-	-	L	L
Methanol	S	S	-	-
Hydrogen cyanide or triazine	-	-	Trace	L
Acetaldehyde	L	S	-	-
1-Butene-3-yne	-	-	S	S
Ethanol	Trace	L	-	-
Chloroethane	-	-	S	L
Trichlorofluoromethane	L	L	L	L
Propanal	L	S	S	-
Propene Nitrile	-	-	S	L
Benzene	-	-	L	L
Dihydropyran	L	S	-	-
Toluene	S	-	S	S

---

[a] Adapted from Einhorn, I. N. 1975. Physiological and toxicological aspects of smoke produced during the combustion of polymeric materials. Environmental Health Perspectives, 11: 163-189.

L = Large S = Small

Table 5-11. Lethal concentrations and OSHA limits of pyrolysis and combustion gases from a polyurethane foam

PRODUCT	LC_{Lo}[a,b] (ppm)	OSHA LIMIT[c,d] (ppm)
Acetaldehyde	4000 (rat/4 h)	200
Benzene	20000 (human/5 min)	10
Carbon dioxide	100000 (human/1 min)	5000
Carbon monoxide	4000 (human/30 min)	50
Ethanol		1000
Hydrogen cyanide	300 (human/10 min)	10
Methanol	1000 (monkey)	200
Propanal	8000 (rat/4 h)	
Propene nitrile	258 (rabbit/4 h)	
Toluene	4000 (rat/4 h)	200
Trichlorofluoromethane	100000 (rat/20 min)	1000

[a] Data from National Institute for Occupational Safety and Health. 1979. Registry of Toxic Effects of Chemical Substances, 1978 edition. DHEW Publication No. 79-100. U.S. Government Printing Office, Washington, DC.

[b] LC_{Lo} is the lowest published lethal concentration for a specific animal. Because animals react to toxic materials differently, values for nonhumans do not necessarily reflect the response of humans. Lethal concentrations do not indicate the magnitude of other toxic effects, such as irritation and carcinogenicity, which may occur at lower concentrations.

[c] Data from Occupational Safety and Health Administration. 1979. Code of Federal Regulations, Title 29, Chapter XVII, Part 1910.1000. U.S. Government Printing Office, Washington, DC.

[d] OSHA has established maximum tolerable exposure limits (8-hour weighted average) for more than 400 gases. The least toxic of these gases is carbon dioxide with a limit of 5000 ppm. The most toxic is nickel carbonyl with a limit of 0.001 ppm.

Bioassay studies, in which time-to-death of rats or mice is commonly used to determine toxicity, emphasize the influence of fire conditions and formulations on the fire toxicity ranking of polymeric materials. Gases from smoldering urethane foams are more toxic than those from burning urethane foams (Wright and Adams 1976). In comparison with nonfire-retarded urethane foams, those with fire retardants have been shown to have lower toxicity under pyrolysis conditions (Hilado 1976), but greater toxicity under combustion conditions (Wright and Adams 1976, Petajan etal 1975). Based on the lowest temperatures at which materials produced toxic pyrolysis gases, fire toxicity of rigid urethane and isocyanurate foams are lower than or lie within the range of conventional materials, such as spruce wood (Kimmerle 1976).

Where To Insulate

Heated areas, especially in cold climates, should be surrounded with insulation by placing it in the walls, ceiling, and floors. It is best to have it as close to the heated space as possible. For example: if an attic is unused, the insulation should be placed in the attic floor rather than in the roof structure.

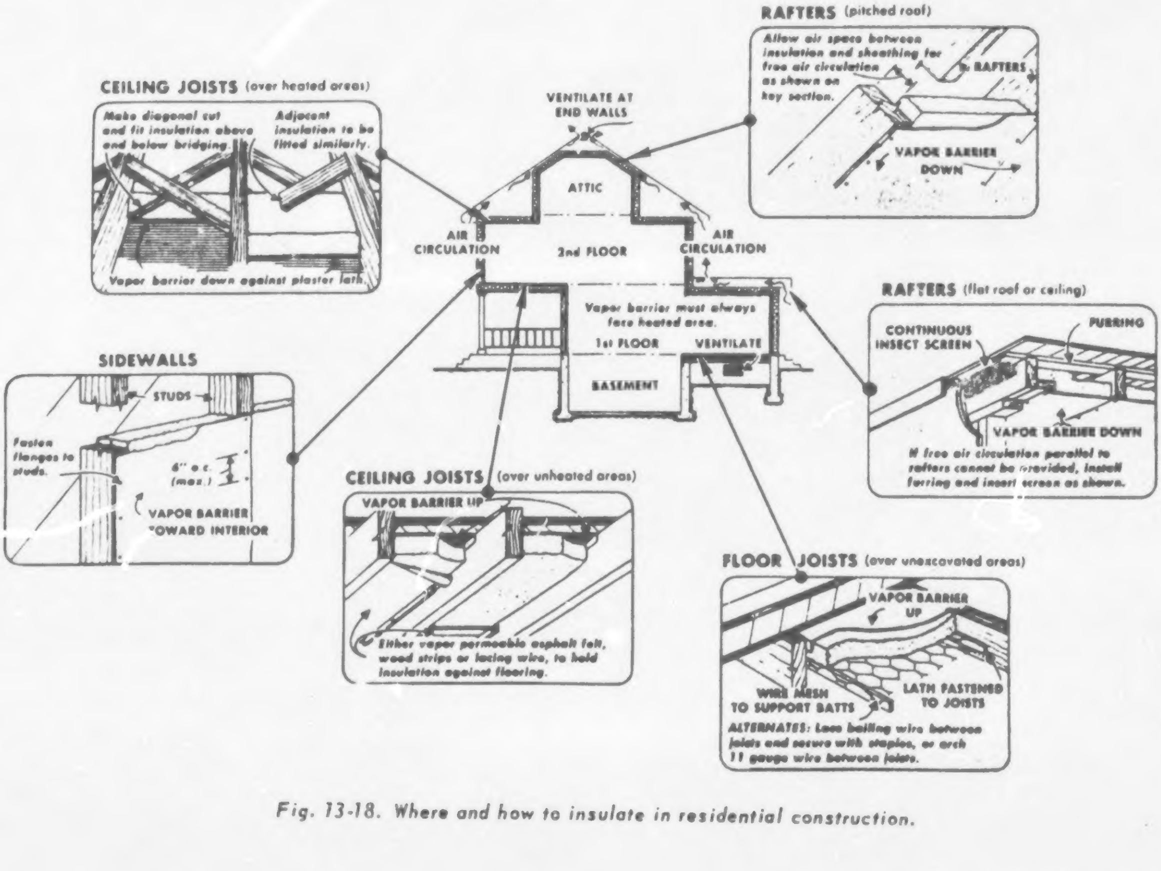

RAFTERS (pitched roof)
Allow air space between insulation and sheathing for free air circulation as shown on key section.
RAFTERS
VAPOR BARRIER DOWN
CEILING JOISTS (over heated areas)
Make diagonal cut and fit insulation above and below bridging.
Adjacent insulation to be fitted similarly.
Vapor barrier down against plaster lath.
VENTILATE AT END WALLS
ATTIC
AIR CIRCULATION
2nd FLOOR
AIR CIRCULATION
Vapor barrier must always face heated area.
1st FLOOR
VENTILATE
BASEMENT
RAFTERS (flat roof or ceiling)
CONTINUOUS INSECT SCREEN
FURRING
VAPOR BARRIER DOWN
If free air circulation parallel to rafters cannot be provided, install furring and insert screen as shown.
SIDEWALLS
STUDS
Fasten flanges to studs.
6" o.c. (max.)
VAPOR BARRIER TOWARD INTERIOR
CEILING JOISTS (over unheated areas)
VAPOR BARRIER UP
Either vapor permeable asphalt felt, wood strips or lacing wire, to hold insulation against flooring.
FLOOR JOISTS (over unexcavated areas)
VAPOR BARRIER UP
WIRE MESH TO SUPPORT BATTS
LATH FASTENED TO JOISTS
ALTERNATES: Lace bailing wire between joists and secure with staples, or arch 11 gauge wire between joists.

Fig. 13-18. Where and how to insulate in residential construction.

If however, it is desirable to heat attic space or certain portions of the area, walls and ceilings should be insulated. Where the insulation is placed in the roof frame, see figure below, be sure to allow space between the insulation and the sheathing for free air circulation. The floors of rooms above unheated garages or porches require insulation if maximum comfort is to be maintained.

Fig. 13-19. Installing blanket insulation between the rafters in an attic area.

Where a basement space is to be remodeled into a room, insulation of the walls is recommended. In addition to saving heat and attaining greater comfort, better acoustical qualities will also be acquired.

When rooms are added to a house or porches are enclosed to provide additional space, insulation should be installed with the same care as in new construction.

Insufficient insulation or ventilation directly under low pitched roofs used in modern construction may cause a special problem. During winter weather, excessive heat escaping from rooms below may cause snow on the roof to melt and water to run down the roof. In reaching the overhang, the water may freeze again causing a ledge or dam of ice to build up. Additional water reaching this dam may back under the shingles and leak into the building.

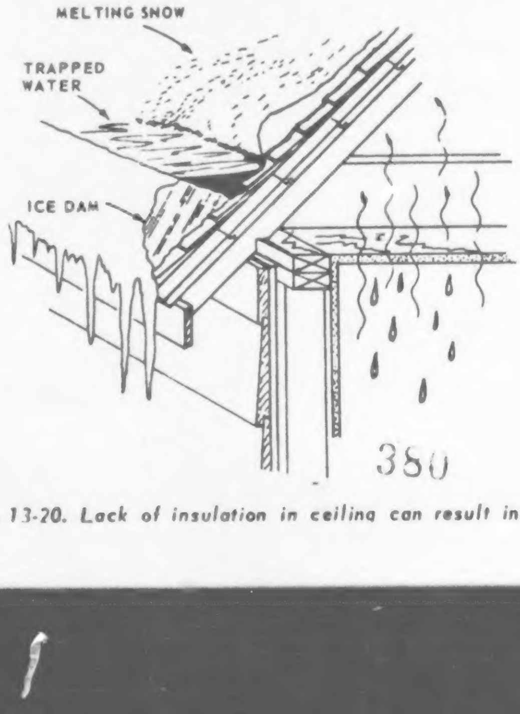


Fig. 13-20. Lack of insulation in ceiling can result in an

Basementless Structures

Floors over unheated space directly above the ground require the same degree of insulation as walls in the same climate zone. This space (called a crawl space) if enclosed by foundation walls, must be ventilated and will therefore approach the outside temperature.

The figure below shows the essential requirements for crawl space insulation and ventilation. A vapor barrier should be positioned either on top of the insulation as shown or between the rough and finish floor. To prevent the insulation from sagging or tearing loose, it should be supported by wire mesh or wooden strips.

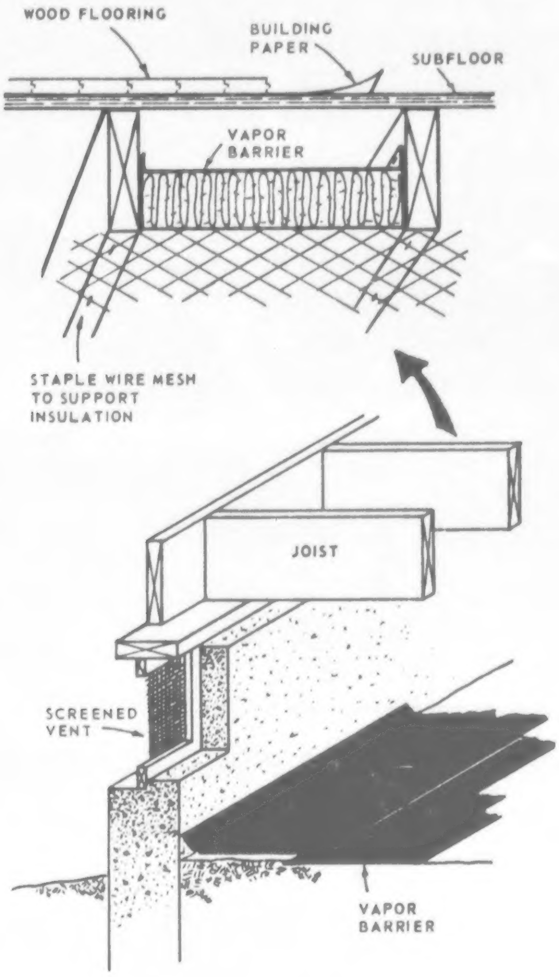

WOOD FLOORING
BUILDING PAPER
SUBFLOOR
VAPOR BARRIER
STAPLE WIRE MESH TO SUPPORT INSULATION
JOIST
SCREENED VENT
VAPOR BARRIER

Fig. 13-21. Essential construction to provide insulation and ventilation for a crawl space. Use roll roofing or polyethylene film for the ground cover.

Moisture coming up through the ground can be controlled by covering it with 4 mil (.004) polyethylene plastic film or roll roofing weighing at least 55 bls. per square. The material should be laid over the surface of the soil with edges lapping at least 4 in.. If the ground is rough, it is advisable to apply a layer of sand or fine gravel before laying the vapor barrier. Covers of this kind greatly restrict the evaporation of water and somewhat less ventilation is needed than when no covers are used. The soil surface below the building should be **above** the outside grade if there is a chance that water might get inside the foundation wall. The soil cover is especially valuable where the water table is continually near the surface, or the soil has high capillarity. Be sure the covering is carried well up along the foundation wall.

Crawl spaces are sometimes closed and used as a plenum (large **heating** duct) to distribute warm air throughout the structure.

Today many homes and other structures are built on concrete slab floors. Such floors should contain insulation and a vapor barrier. The figure below shows how the heat flows for a slab floor. The loss is concentrated along the perimeter. Very little heat is lost into the ground under the central part of the floor. Although the vapor barrier must be continuous under the entire floor only the perimeter needs to be insulated. The insulation can be installed horizontally (about 2 ft.) under the floor or vertically along the foundation walls as shown in the figure below.

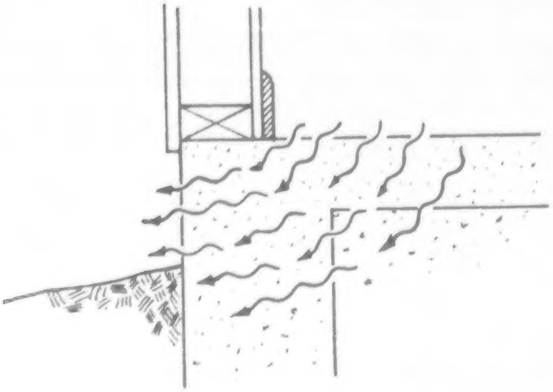


Fig. 13-22. How heat is lost from a concrete slab floor.

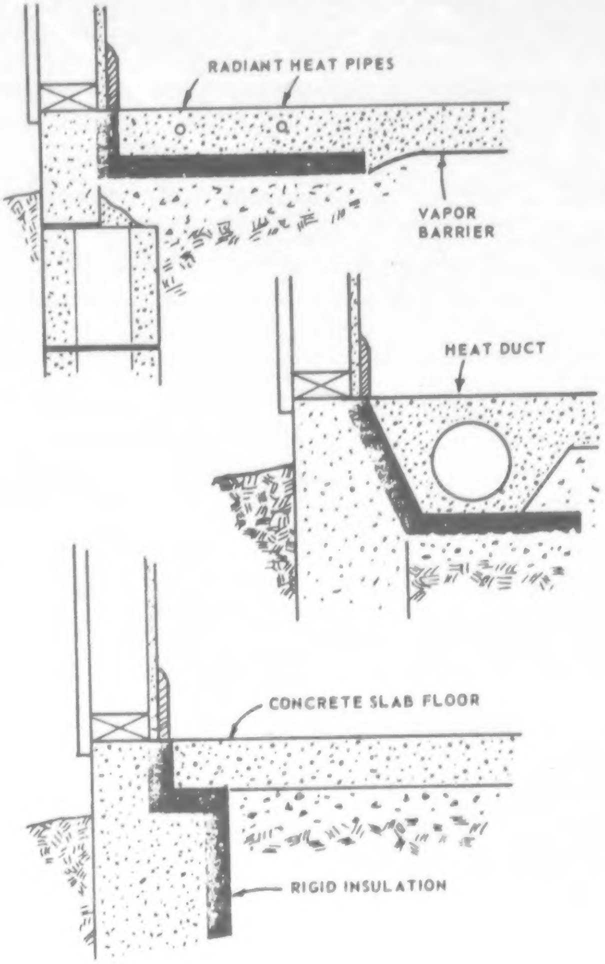


Fig. 13-23. Typical methods of installing perimeter insu-

Condensation

Moisture in the form of water vapor is always present in the air. It acts like a gas and penetrates wood, stone, concrete and most other building materials. Warm moisture-laden air within a heated building forms a vapor pressure which constantly seeks to escape and mix with the colder, drier air outside.

Water vapor results from many sources within a living space. It is generated by cooking, bathing, clothes washing, and drying, or by humidifiers which are often used to maintain a comfortable level of humidity.

When warm air is cooled, some of its moisture will be released as condensation. The temperature at which this occurs for a given sample of air is called the dew point. If you live in a colder climate - any region where the January temperature is 25 deg. F or less - the dew point can occur within the wall structure or even within the insulation itself. The resulting condensation will reduce the efficiency of the insulation and may cause permanent damage to the structural members over a period of time.

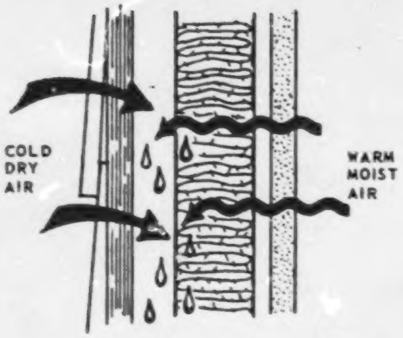
Moisture that collects within a wall during the winter months usually finds its way to the exterior finish in the spring and summer, causing deterioration of siding and/or paint peeling. The siding is usually a porous material and will hold a considerable amount of moisture. The paint is non-porous and as a result the moisture gathers under the paint film, causing blisters and separation from the wood surface. Recent developments in paint manufacturing have provided products that are somewhat porous and permit moisture to pass through, thus minimizing this problem in structures without adequate vapor barriers.

During warm weather, condensation may occur in basement areas or on concrete slab floors in contact with the ground. When warm humid air comes in contact with cool masonry walls and floors, some of the moisture will condense causing wet surfaces. Covering these surfaces with insulation will minimize condensation. Operating a dehumidifier in areas surrounded by cool surfaces will prove helpful during humid weather.

THE "DEW POINT" IS THE TEMPERATURE AT WHICH THE AIR IS COMPLETELY SATURATED WITH MOISTURE. ANY LOWERING OF THE AIR TEMPERATURE WILL CAUSE CONDENSATION TO OCCUR.

Vapor Barriers

A properly installed vapor barrier (membrane through which water vapor cannot readily pass) will protect ceilings, walls, and floors from moisture originating within a heated space. See figure on next page. Within an insulated wall or construction, the temperature will be warm on the inside and cool on the outside. The vapor barrier must be located on the WARM SIDE to prevent moisture from moving through the insulation to the cool side and condensing.


COLD
DRY
AIR
WARM
MOIST
AIR

WALL WITH NO VAPOR BARRIER

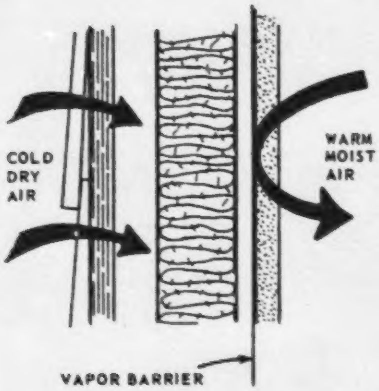

COLD
DRY
AIR
WARM
MOIST
AIR
VAPOR BARRIER

Fig. 13-24. How a vapor barrier protects a wall from condensation.

Many of the insulation materials produced today have a vapor barrier applied to the inside surface. Also, many interior wall surface materials are backed with vapor barriers. When these materials are properly applied they usually provide satisfactory resistance to moisture penetration.

If the insulating materials do not include a satisfactory vapor barrier, then one should be installed as a separate element. Vapor barriers in wide continuous rolls include: asphalt-coated paper; aluminum foil, see below; polyethylene films, see below; and various combinations of these materials. To prevent accidental puncturing, it should be installed after heat ducts, plumbing, and electrical wiring are in place. Cut and carefully fit the barrier around such openings as outlet boxes.

Some architects specify the use of 4 or 6 mil polyethylene film, making a continuous cover over walls, ceilings, and windows just before the plaster base or wallboard is applied. The covering protects the window unit during plastering operations; permits light to enter; and can easily be trimmed out of the opening just before the finished wood trim is installed.

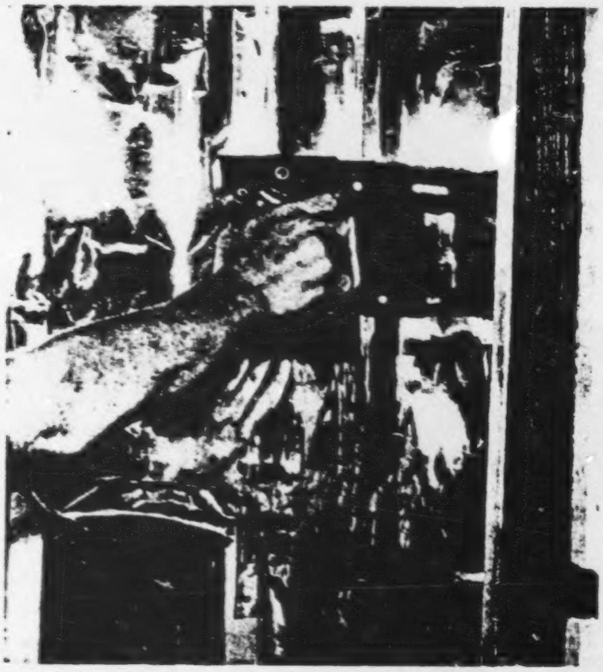


Fig. 13-25. Aluminum foil provides a good vapor barrier when joints are carefully lapped.

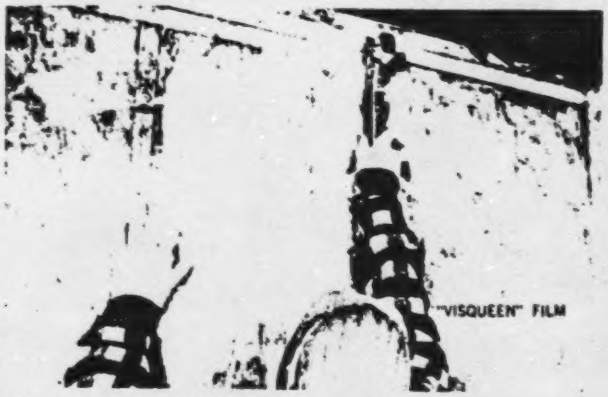


Fig. 13-26. Installing vapor barrier (4 or 6 mil polyethylene film). Staple securely at top and bottom plates and around door and window openings. (Owens-Corning Fiberglas Corp.)

Ventilation

In addition to the proper placement of vapor barriers, adequate ventilation of the construction will help to insure against moisture problems. The cold side (outside) of walls should be weathertight but still permit the wall to "breathe". Building paper can be used over wood sheathing to reduce infiltration if it is not waterproof and will permit moisture within the wall to escape.

It is especially important to provide ventilation for an unheated attic or space directly under a low pitched or flat roof. The figure below shows the most common systems for ventilation and the recommended size of the vent area. For a standard gable roof, vents like the one shown below, are located in each end; providing a total ventilating area equal to 1/300 of the ceiling area.

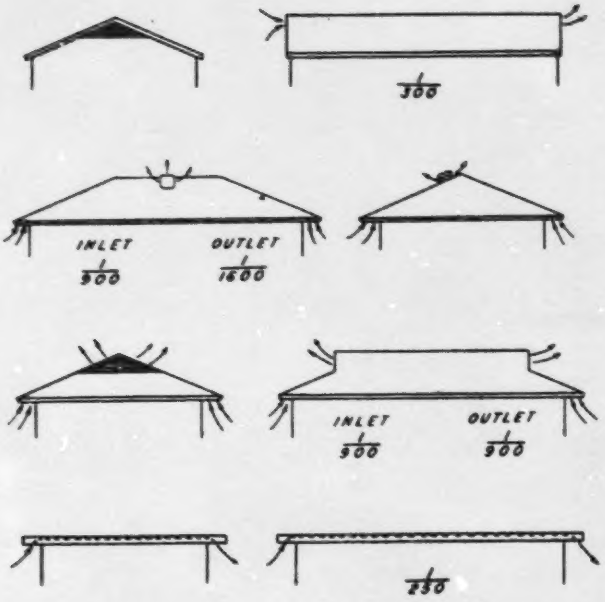


Fig. 13-27. *Ventilation requirements for various types of roofs. The figures indicate the fractional part of the total ceiling area to be used in the vents.*

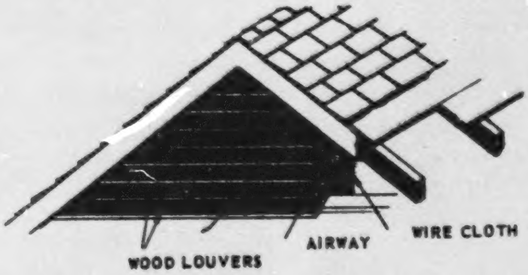


Fig. 13-28. *Louver-type ventilator for a gable or Dutch hip roof. Vent opening should be designed to keep snow and rain from entering and should also be screened against insects.*

Figure 29 shows a method of ventilating a cornice section. A wide range of prefabricated ventilators for roofs, gable ends, and cornices are available. One type of roof ventilator is shown in figure 30. Figure 31 describes one model that is manufactured in many sizes.

Ventilators that are located in the roof surface may result in leaks if not properly installed. Whenever possible these ventilators should be installed on a section of the roof that slopes to the rear. Under-roof ventilation is especially important in low-sloped roofs to prevent excessive accumulation of hot air during summer months. Sometimes it may be possible to utilize a false flue or a section of a chimney for attic ventilation, figure 32.

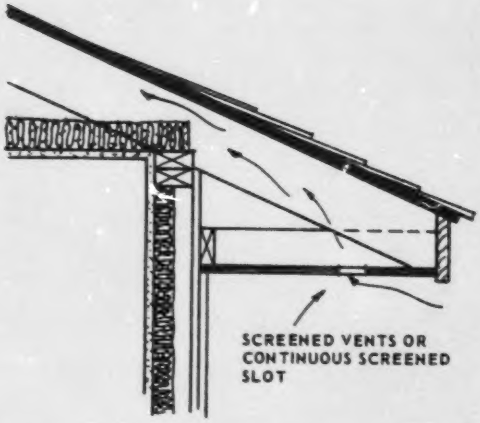

SCREENED VENTS OR
CONTINUOUS SCREENED
SLOT

Fig. 13-29. Vents located in the building cornice. Be sure there is free access of the air to the attic area.

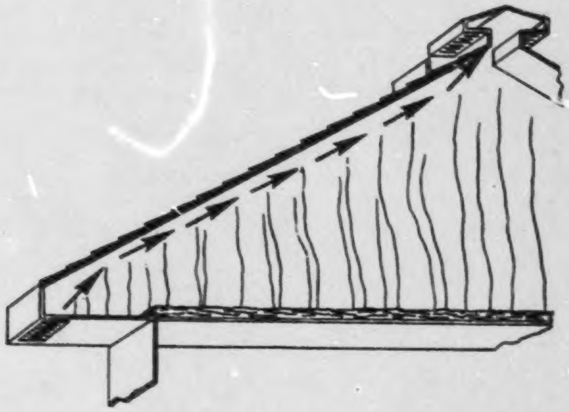


Fig. 13-30. Ridge ventilator provides uniform airflow from soffit to ridge.

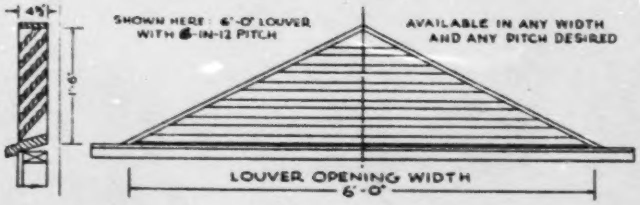

4½"
1'-6"
SHOWN HERE: 6'-0" LOUVER
WITH 6-IN-12 PITCH
AVAILABLE IN ANY WIDTH
AND ANY PITCH DESIRED
LOUVER OPENING WIDTH
6'-0"

Fig. 13-31. Prefabricated wood ventilator furnished completely assembled and ready to install.
(Ideal Co.)

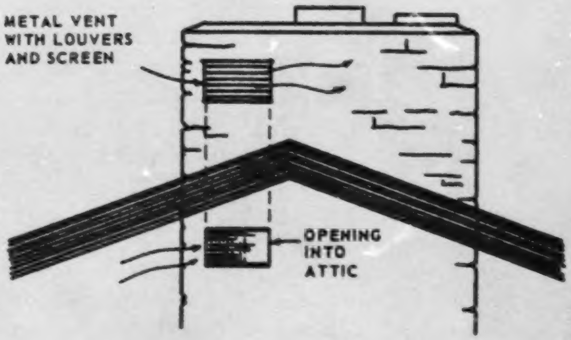

METAL VENT
WITH LOUVERS
AND SCREEN
OPENING
INTO
ATTIC

Fig. 13-32. Using a section of a chimney for attic ventilation.

Wall structures of existing frame buildings that indicate inadequate "cold side" ventilation can be corrected by installing patented ventilators as shown in figure 33. Most of these units consist of a metal tube with a cover that includes tiny louvers. They are installed by simply pressing them into a hole bored through the siding and sheathing - in each stud space. For maximum ventilation, install one at the bottom of the wall and one at the top.

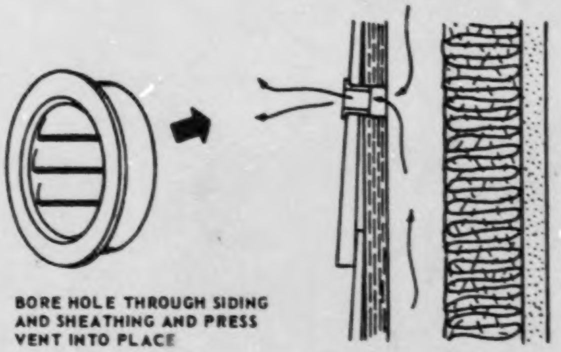


Fig. 13-33. Miniature vents installed in existing structures. 1 in. size is usually sufficient for most wall structures. Sizes range from 1 to 4 in.

Installing Batts and Blankets

Insulation materials must be properly installed if they are to perform efficiently. Even the best insulation will not provide its rated resistance to heat flow if the manufacturer's instructions are not followed or if it is torn or otherwise damaged during or after installation.

Blankets or batts can be cut with a fine-tooth, crosscut hand saw; shears or a large knife. Measure the space and then cut the insulation 2 to 3 in. longer. Remove a portion of the batt from each end so that you will have a flange of the backing or vapor barrier to staple to the framing.

When working with blanket insulation, it is usually best to mark the required length on the floor, and then unroll the blanket. align it with the marks and cut the required number of pieces. For wall installation, first staple the top end to the plate and then staple down along the studs, aligning the blanket carefully. Figure 34 on next page. Finally secure the bottom edge to the sole plate.

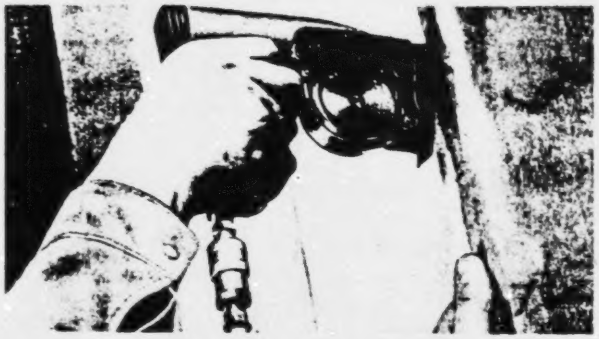


Fig. 13-34. Installing blanket insulation using an air driven stapler. (Spotnails Inc.)

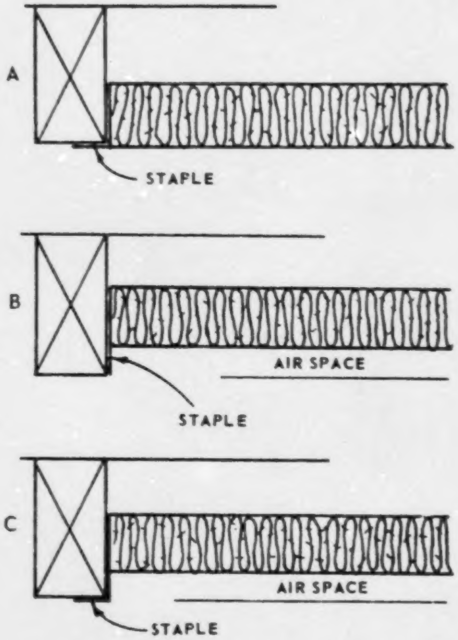


Fig. 13-35. Methods of installing blankets and batts. A–Flush with inside surface of stud. B–Flange stapled along side of stud to form air space. C–Special flange.

To install batts in a wall section, place the unit at the bottom of the stud space and press it into place. Start the second batt at the top with it tight against the plate. Sections can be joined at the midpoint by butting them together. The vapor barrier should be overlapped at least 1 in. unless a separate one is installed. Some batts are designed without covers or flanges and are held in place by friction.

Flanges, common to most blankets or batts, are stapled to the face or side of the framing members, figure 35. Pull the flange smooth and space the staples no more than 12 in. apart. The interior finish, when applied, will serve to further seal the flange in place when it is fastened to the stud face. Some blankets have special folded flanges which enable them to be fastened to the face of the framing and also form an air space as shown in C, figure 35.

In dry wall construction, specifications may require that the faces of the framing be left uncovered. When so applied, the flanges of the insulation should fit smoothly to the sides of the framing and the staples should be spaced 6 in. or closer. Be sure that all gaps or "fish mouths" (wrinkles) are eliminated. When it is necessary to secure maximum vapor protection, a separate vapor barrier should be applied over the entire wall or ceiling area. Avoid any perforations and lap joints fully.

Thread the insulation carefully behind any drain pipes that might be located in the wall as shown in figure 36. If water service pipes (in cold climates they should never be located in outside walls) are present, it is well to add a separate vapor barrier between the pipe and interior surface to prevent moisture condensation on the cold pipe.

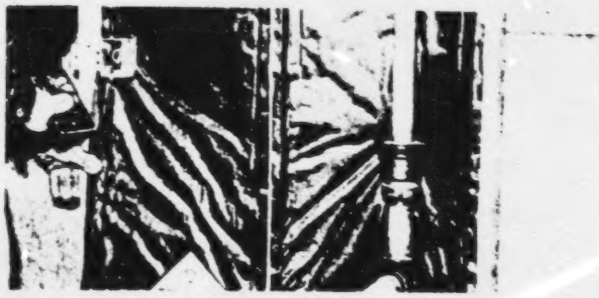


Fig. 13-36. Insulation should be fitted carefully around plumbing pipes and electrical outlet boxes. (Acoustical and Board Products Assoc.)

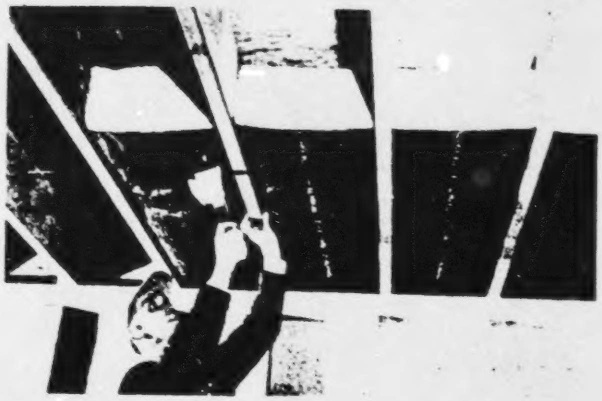
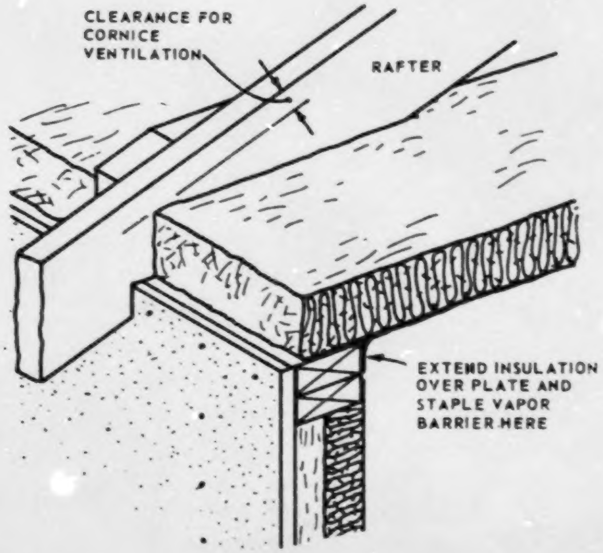


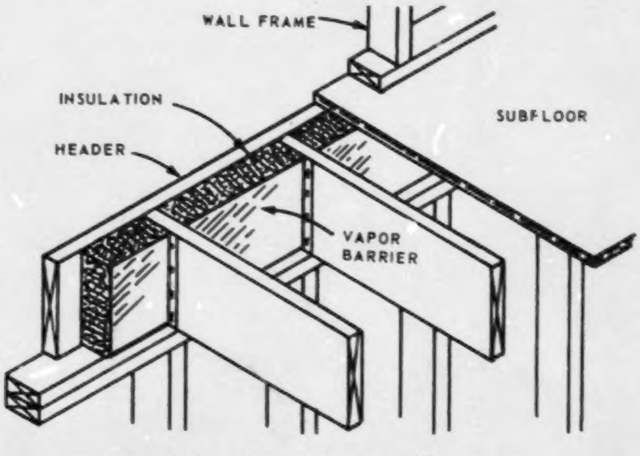
Fig. 13-37. Installing batts between ceiling joists. Use at least an 8 in. thickness when heating cables are located in the ceiling surface.

Ceiling insulation can be installed from below or from above if attic space is accessible. When batts are used they are usually installed from below as shown in figure 37, following about the same general procedure as recommended for walls. They must be butted snugly together at the ends and carried out over the outside wall plates, figure 38. In multi-story construction, especially in cold climates, the perimeter of floor frames should be insulated as shown in figure 39. Insulation should also be installed in the perimeter of the main floor even though the basement area will be heated. Cut and fit pieces so they will fit snugly between the joists and against the header, see figure 40.



CLEARANCE FOR CORNICE VENTILATION
RAFTER
EXTEND INSULATION OVER PLATE AND STAPLE VAPOR BARRIER HERE

Fig 13-38 Placement of ceiling insulation at outside wall



WALL FRAME
INSULATION
SUBFLOOR
HEADER
VAPOR BARRIER

Fig. 13-39. Insulating perimeter of floor frame.

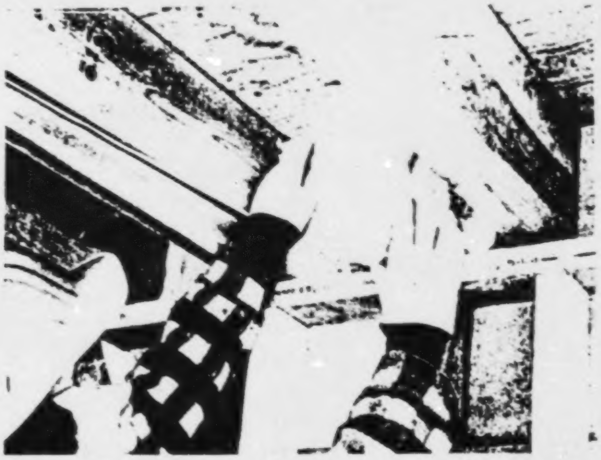


Fig. 13-40. Install sections of insulation around perimeter of a floor frame. (Owens-Corning Fiberglas Corp.)

WHEN INSTALLING CEILING INSULATION FROM BELOW, WEAR TIGHT FITTING CLOTHING AND A CAP OR HAT WITH A WIDE BRIM. GOGGLES MAY ALSO BE HELPFUL. THIS IS ESPECIALLY IMPORTANT WHEN WORKING WITH INSULATION MADE OF TINY GLASS FIBERS WHICH MAY IRRITATE YOUR SKIN OR EYES.

Follow the procedure of completing large wall and ceiling areas first, and then insulate the odd sized spaces and areas above and below windows. Thus, small cuttings remaining from the main areas can be used. Take the time necessary to carefully apply the insulation (and vapor barrier) around electrical outlets and other wall openings. Be certain that you do not cover outlet boxes or they may be missed when the wall surface is applied.

A thorough insulation job will require that all spaces be filled. For example; the space between window and door frames, and the rough framing as shown in figure 41. Cuttings left over from larger spaces can be utilized. Pack the insulation into the small space with a stick or screwdriver and then cover the area with a vapor barrier.

A floor projection, figure 42, may be used to carry a chimney chase, bay window unit, or simply to extend the size of the room above. This construction must be carefully insulated. Since there is no inside wall surface to form a seal against infiltration, the sheathing must be tight and the insulation flange and/or vapor barrier must be carefully stapled to the sides of the joist as shown. If weather conditions permit, this segment of insulation could be installed before the subfloor is laid. This would simplify installation since the work could be done from above.

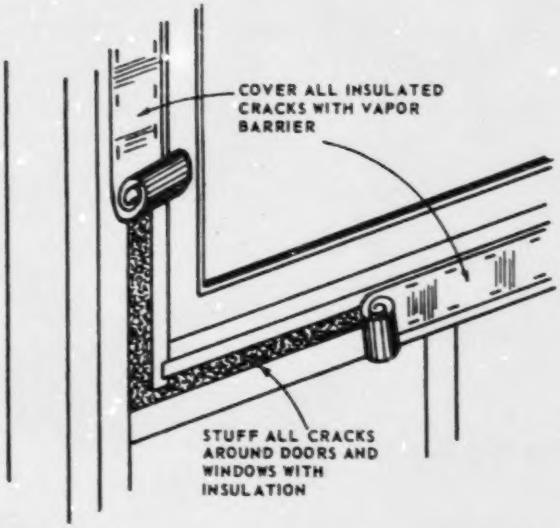

COVER ALL INSULATED CRACKS WITH VAPOR BARRIER
STUFF ALL CRACKS AROUND DOORS AND WINDOWS WITH INSULATION

Fig. 13-41. Insulate around window and door frames.

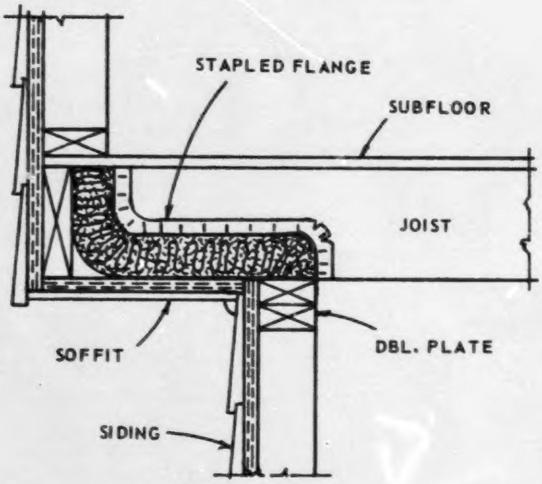

STAPLED FLANGE
SUBFLOOR
JOIST
SOFFIT
DBL. PLATE
SIDING

Fig. 13-42. Insulating a floor projection. Attach flanges and vapor barrier to side of joist.

Installing Fill Insulation

Fill insulation is poured or blown into place. It is especially adaptable to existing structures where "blown-in" fill may be used, without resorting to extensive alteration in the wall surfaces.

Ceilings are easily insulated with fill materials. It is poured directly from bags into the joist spaces and then leveled with a straight-edge as shown in figure 43. A vapor barrier should be installed on the underside of the joists before the ceiling finish is applied. It will control the flow of moisture and also prevent fine particles (present in some forms of fill insulation) from sifting through cracks that might develop in the ceiling.

Fill insulation is often poured into the core of block walls, see figure 44, or in the space in masonry cavity walls. Thermal resistance is greatly increased. For example, the "U" factor of a standard concrete block (.53) is reduced to .36 when the cores are filled with insulation. A lightweight 8 in block will be reduced from .33 to .17.

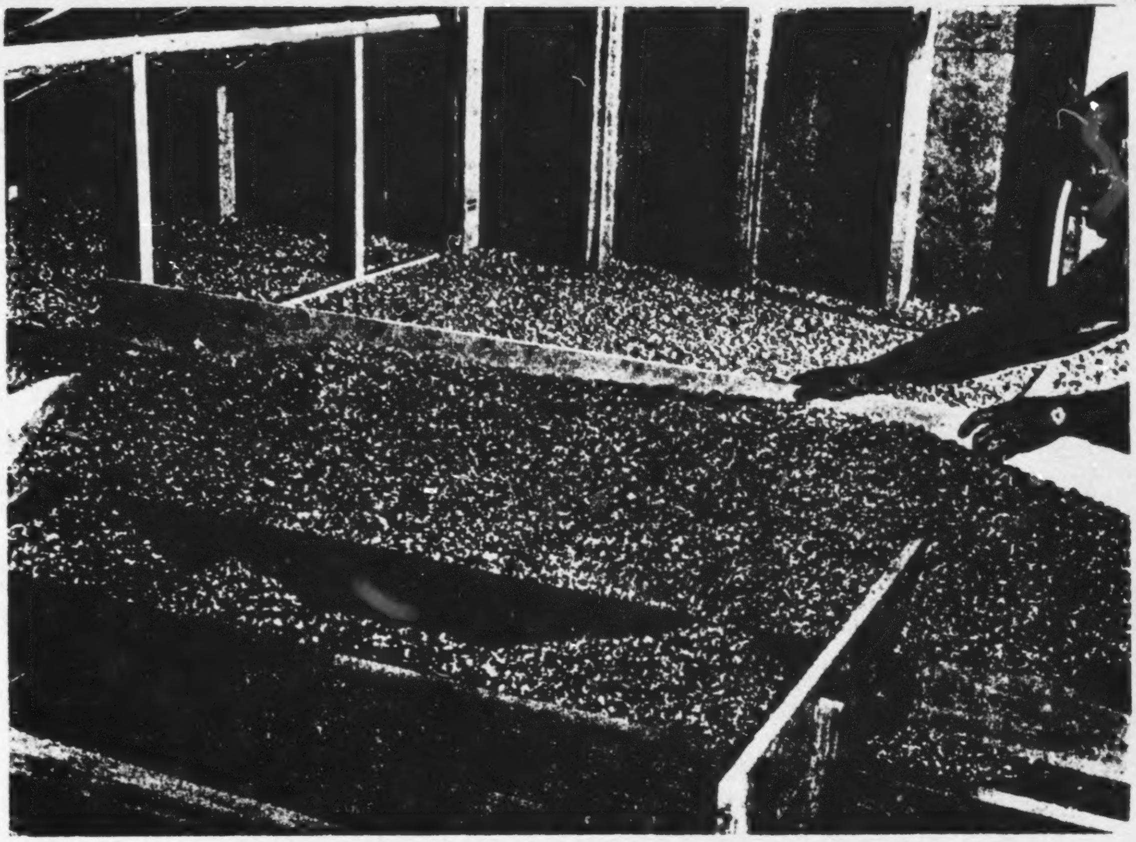


Fig. 13-43. Leveling fill insulation over ceiling joists. (Vermiculite Institute)

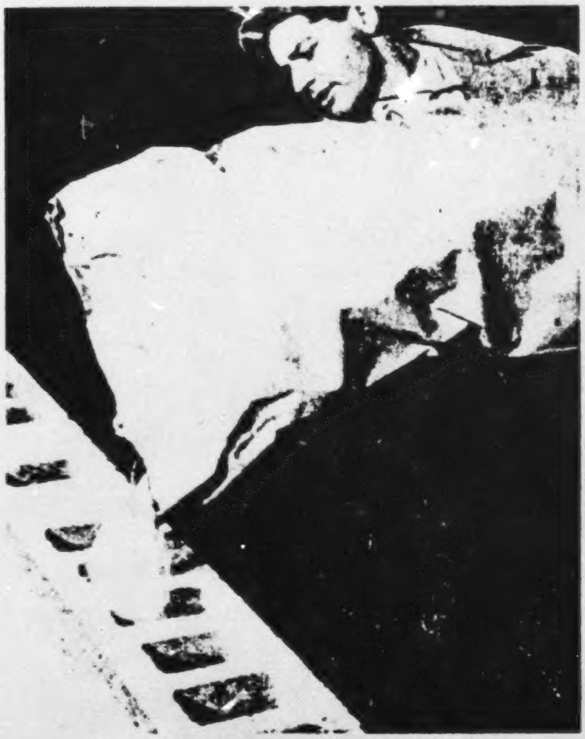


Fig. 13-44. Filling cores of concrete block walls with insulation. (Perlite Institute, Inc.)

Installing Rigid Insulation

The installation of slab or block insulation varies with the type of product. The manufacturers' specifications should always be studied and carefully followed.

Insulating board is used extensively for exterior walls. Sometimes it is used as the sheathing material for roofs or simply as an insulating material installed over the roof deck. A number of products are especially designed to insulate concrete slab floors. See figure 45. Waterproof materials such as glass fibers or foamed plastic provide desirable characteristics.

Figure 46 shows a plastic foam insulation board applied to a masonry wall. It is bonded to the basic wall surface with a special mastic and provides a permanent insulation and vapor barrier. After the boards are installed, conventional plaster coats can be applied to the surface. Plastic foam (Styrofoam) insulation has gained wide acceptance as a rigid insulating material and has been successfully applied to a wide variety of constructions.

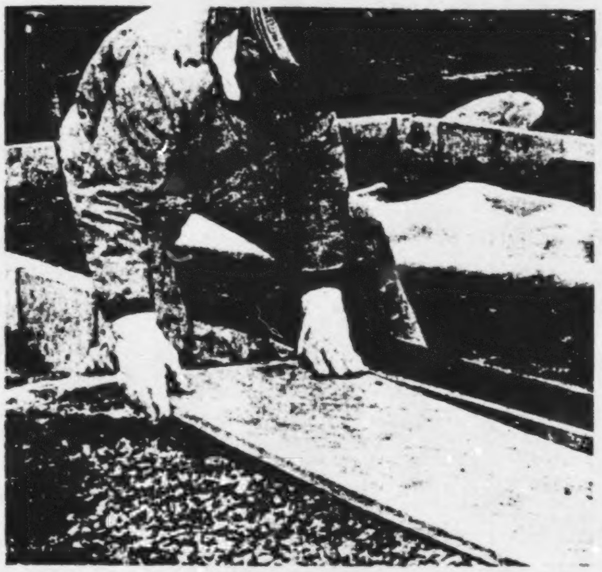


Fig. 13-45. Installing a rigid form of insulation in the perimeter of a slab floor. (Owens-Corning Fiberglas Corp.)

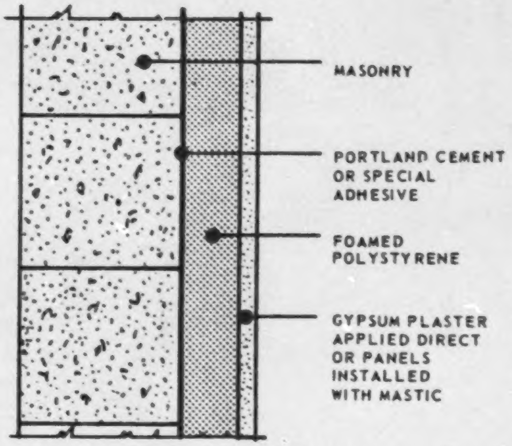

MASONRY
PORTLAND CEMENT OR SPECIAL ADHESIVE
FOAMED POLYSTYRENE
GYPSUM PLASTER APPLIED DIRECT OR PANELS INSTALLED WITH MASTIC

Fig. 13-46. Insulating a masonry wall with rigid insulation board made from foamed polystyrene "Styrofoam."

Insulating Basement Walls

When basements will be used as living space, exterior walls should be insulated. The outside surface of masonry walls should be waterproofed below grade and include a footing drain. The inside surface could be finished as shown in figure 46, or furring strips could be used to form a cavity for the insulation and provide a nailing base for surface materials.

In cold climates a framework of 2 x 4 studs, spaced 24 in. O.C. is often used. See figure 47. Use concrete nails or mastic to secure the sole plate and fasten the top plate to the joists or still. Unfaced insulation will require a separate vapor barrier.

Fig. 13-47. Insulation is placed in a framework attached to a masonry wall. (Owens-Corning Fiberglas Corp.)

Insulating Existing Structures

Special precautions must be taken when insulating an existing structure where no vapor barrier can be installed. Inside humidities should be controlled. "Cold side" ventilation is essential. A fairly satisfactory vapor barrier can be secured by applying: two coats of either lead and oil paint, rubber emulsion paint, or aluminum paint; or a vapor barrier wall paper. The application should be carefully made on all surfaces of outside walls and ceiling.

REFERENCES

Abrams, D.W. 1978. Installation and operation problems encountered in residential solar systems. In Preconference Proceedings - Solar Heating and Cooling Systems Operational Results. U.S. Department of Energy. SERI/TP-49-063 Preliminary.

Allan, G.G., J. Dutkiewicz, and E.J. Gilmartin. 1980. Long-term stability of area-formaldehyde foam insulation. Environmental Science and Technology, 14:1235-1240.

Anderson, B. 1975. The sun in a drawer. Environment, 17(7): 36-40.

Anderson, R. W. and P. Wilkes. 1977. Survey of cellulosic insulation materials. ERDA 77-23. U.S. Energy Research and Development Administration. Washington, DC. (Available from NTIS, Springfield, VA.)

Armstrong. 1979. Armaflex II Sheet Insulation. Advertising bulletin. IP-907-679J. Armstrong Cork Company, Lancaster, PA.

Armstrong. 1979. Accotherm Pipe Insulation. Advertising bulletin. IP-872-979J. Armstrong Cork Company, Lancaster, PA.

Ashida, K., F. Yamauchi, M. Katoh, and T. Harada. 1974. HCN generation from urethane and isocyanurate foams. Journal of Cellular Plastics, July/August 1974: 181-185+.

Betz, G. M. 1978. Attack thermal insulation's problems now. Fire Journal, September 1978: 50-51.

Blaga, A. 1978. Use of plastics in solar energy applications. Solar Energy, 21: 331-338.

Bowes, P. C. 1974. Smoke and toxicity hazards of plastics in fire. Annals of Occupational Hygiene, 17: 143-157.

Cash, M. 1978. Hardware problems encountered in solar heating and cooling systems. DOE/NASA TM-78172. Technical Memorandum. (Available from NTIS, Springfield, VA.)

Chamberlain Manufacturing Corporation. 1976. Technical data on the Chamberlain Manufacturing Corporation flat plate solar collector. Chamberlain Manufacturing, Elmhurst, IL.

Committee on Fire Safety Aspects of Polymeric Materials. 1979. Fire Safety Aspects of Polymeric Materials, Volume 5: Elements of Polymer Fire Safety and Guide to the Designer. Publication NMAB 318-5. National Academy of Sciences, Washington, DC.

Committee on Impacts of Stratospheric Change. 1979. Protection against depletion of stratospheric ozone by chlorofluoromethanes. National Academy of Sciences, Washington, DC.

Conning, D. M., M. J. Hayes, J. A. Styles and J. A. Nicholas. 1970. Comparison between in vitro toxicity of dusts and certain polymers and minerals and their fibrogenicity. Inhaled Particulates, 1: 499-506.

Copper Development Association, Inc. 1978. Solar Energy Systems. Copper Development Association, Inc., New York, NY.

Cornish, H. H., K. J. Hahn, and M. L. Barth. 1975. Experimental toxicology of pyrolysis and combustion hazards. Environmental Health Perspectives, 11: 191-196.

Dow Chemical U.S.A. 1979. Styrofoam brand insulation design information and specifications. Publication 7.14 Do. Form No. 179-4129-78. Dow Chemical U.S.A., Midland, MI.

DuPont. 1978. Freons - fluorocarbons - properties and applications. Freon product information bulletin B - 2. E. I. DuPont de Nemours and Company, Inc., Wilmington, DE.

Einhorn, I. N. 1975. Physiological and toxicological aspects of smoke produced during the combustion of polymeric materials. Environmental Health Perspectives, 11: 163-189.

Factory Mutual Research. 1975. A fire study of rigid cellular plastic materials for insulated wall and roof/ceiling constructions (Part III). Factory Mutual Engineering Corporation, Norwood, MA.

Factory Mutual Research. 1974. A fire study of rigid cellular plastic materials for insulated wall and roof/ceiling constructions (Part II). Factory Mutual Engineering Corporation, Norwood, MA.

Factory Mutual System. 1978. Approval Guide. Factory Mutual Engineering Corporation, Norwood, MA.

Gaskill, J. R. 1973. Smoke development in polymers during pyrolysis or combustion. In C. J. Hilado (ed.) Smoke and Products of Combustion. Technomic Publishing Company, Westport, CT. Reprinted from Journal of Fire and Flammability.

Gilleland, F. W. 1980. Insulation for solar collectors important to heat loss control. Solar Engineering, January 1980: 20-21.

Hilado, C. J. 1979. Laboratory test methods for evaluating the fire response of materials. Fire Journal, November 1979: 69-75+.

Hilado, C. J. 1969. Flammability Handbook for Plastics. Technomic Publishing Company, Inc., Westport, CT.

Hilado, C. J. 1974. Flammability Handbook for Plastics, 2nd edition. Technomic Publishing Company, Inc., Westport, CT.

Hilado, C. J., H. J. Cumming, and C. J. Casey. 1978. Relative toxicity of materials in fire situations. Modern Plastics, April 1978:92-96.

Hilado, C. J., H. J. Cumming, and A. N. Solis. 1977. Relative toxicity and flash fire propensity of the pyrolysis gases from polyurethane foams. Journal of Cellular Plastics, November/December: 408-415.

Hilado, C. J., A. Furst, and W. H. Marcussen. 1976. The use of the NASA animal exposure chamber in fire toxicity tests. Pro. West. Pharmacol. Soc. 19: 397-400 (1976).

Hilado, C. J. and J. E. Schneider. 1977. Toxicity studies of a polyurethane rigid foam. Journal of Combustion Toxicology, 4: 79-86.

Johns-Manville. 1978. Insulations systems, thermal/acoustical insulation products. IND-3211, Johns-Manville, Denver, CO.

Kimmerle, G. 1976. Toxicity of combustion products with particular reference to polyurethane. Annals of Occupational Hygiene, 19: 269-273.

Malhotra, H. L. 1977. The behavior of polymers used in building construction. British JFRO.

Malloy, J. F. 1969. Thermal insulation. Van Nostrand Reinhold Company, New York, NY.

Maugh, T. H., II. 1980. Ozone depletion would have dire effects. Science, 207: 394-395.

MICA. 1979. Commercial and Industrial Insulation Standards. Midwest Insulation Contractors Association, Inc., Omaha, NE.

Montgomery, R. H. 1978. The Solar Decision Book; Your Guide to Making a Sound Investment. Dow Corning Corporation, Midland, MI.

National Foam Products, Inc. Technical information and physical properties of Mr. Foamy. Advertising brochure. National Foam Products, Inc., Paducah, KY.

Neisel, R. H. and H. F. Remde. 1966. Thermal insulation. In Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition, Volume 11. John-Wiley, New York, NY.

Nichols, R. L. 1978. Owens Illinois Liquid Solar Collector Materials. Technical support package. Brief no. MFS-23926. National Aeronautics and Space Administration. Marshall Space Flight Center, AL.

Occupational Safety and Health Administration. 1979. Code of Federal Regulations, Title 29, Chapter XVII, Part 1910.1000. U.S. Government Printing Office, Washington, DC.

Ontario Research Foundation. 1977. The development of methods of reducing corrosion in solar collectors. Technical report. Final report No. 7-77. Ontario Research Foundation. Mississauga, Ontario, Canada.

Petajan, J. H. et al. 1975. Extreme toxicity from combustion products of a fire-retarded polyurethane foam. Science 187: 742-744.

Rapperswill Corp. 1976. Rapco-foam foamed-in-place thermal and acoustical insulation. 7.14 Ra. Rapperswill Corporation, New York, NY.

Rhode Island Energy Corporation. 1978. Test Report ASTM E-84. Rhode Island Energy Corporation, Providence, RI.

Sparkes, H. R. and K. Raman. 1978. Lessons learned on solar system design problems from the HUD solar residential demonstration program. In Conference Proceedings - Solar Heating and Cooling Systems Operational Results. U.S. Department of Energy. SERI/TP-49-063.

Stahl, J. A. 1978. Using foam plastic insulation safely. Fire Journal, September 1978: 43-47+.

Skochdopole, R. E. 1966. Foamed plastics. In Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition, Volume 9. John-Wiley, New York, NY.

Vorhees, K. J., I. N. Einhorn, F. D. Hileman, L. H. Wojsik. 1975. The identification of a highly toxic bicyclophosphate in the combustion products of a fire-retarded urethane foam. Polymer Letters Edition, 13: 293-297.

Weinstein, S. D. 1978. Solar systems design and installation concerns. In Conference Proceedings - Solar Heating and Cooling Systems Operational Results. U.S. Department of Energy. SERI/TP-49-063.

Wright, P. L. and C. H. Adams. 1976. Toxicity of combustion products from burning polymers: development and evaluation of methods. Environmental Health Perspectives, 17: 75-83.

U.S. Department of Housing and Urban Development. 1978. Building the Solar Home. HUD-PDR-276-1. (Available from U.S. Government Printing Office, Washington, DC.)

U.S. Mineral Products Company. 1975. Suprathane insulation/sheathing. 7.14/unt. U.S. Mineral Products Company, Stanhope, NJ.

U.S. Mineral Products Company. Cellofoam expanded styrene building insulation. U.S. Mineral Products Company, Stanhope, NJ.

INSULATION WORKSHEET

EXPOSURE CONDITIONS	Materials in contact with insulation during normal operation: Materials in contact with insulation during abnormal operation: Linear expansion coefficients of associated materials: Temperature of insulation at stagnation: Exposure to UV radiation: Exposure to humidity: Exposure to outdoor atmosphere:	
FUNCTIONAL PROPERTIES	THERMAL CONDUCTIVITY	The lower the thermal conductivity, the more desirable. See Table 5-1. Benchmark: mineral fiber (rock wool) has thermal conductivity of 0.25 to 0.38 Btu-in/ft^2/h/°F.
ENVIRONMENTAL AND SAFETY CONSIDERATIONS	UPPER TEMPERATURE LIMIT	A limit above the temperature reached at stagnation is desirable. See Table 5-1.
	OUTGASSING	The lower the amount and rate of outgassing, and the higher the temperature at which outgassing begins, the more desirable. See Tables 5-2, 5-3, and 5-4.
	LINEAR EXPANSION COEFFICIENT	The closer the coefficient is to the coefficients of other system materials, the more desirable. See Table 5-5. Benchmark: glass has a coefficient of 5 to 9 x 10^{-6}/°F.
	FIRE PROPENSITY	The lower the ignitability, flame spread, and fuel contributed, the more desirable. See Tables 5-6, 5-7, and 5-8. Benchmark: for the ASTM E84 tunnel test, red oak wood has a flame spread rating of 100 and fuel contributed rating of 100. For the ASTM 162 radiant panel test, red oak wood has a flame spread rating of 99.
	SMOKE EMISSION	The lower the smoke emission, the more desirable. See Tables 5-6, 5-7, and 5-9. Benchmark: for the ASTM E84 tunnel test, red oak wood has a smoke density of 100. For the NBS smoke chamber test, red oak wood has a flaming rating of less than 250, and a nonflaming rating of 395.
	FIRE TOXICITY	The lower the toxicity of combustion and pyrolysis gases (indicated by higher LC_{LO}s, allowable exposure limits, and times-to-death of animals), the more desirable. See Tables 5-10 through 5-13.

INSULATION WORKSHEET

	PRODUCT GENERIC TYPE	PRODUCT GENERIC TYPE	PRODUCT GENERIC TYPE	PRODUCT GENERIC TYPE
THERMAL CONDUCTIVITY				
UPPER TEMPERATURE LIMIT OUTGASSING LINEAR EXPANSION COEFFICIENT FIRE PROPENSITY SMOKE EMISSION FIRE TOXICITY				

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

ELECTRICAL PRACTICES

STUDENT MATERIAL

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

ELECTRICAL PRACTICES

ENTRANCE SERVICE

Electricity is distributed on high power lines by the power companies and these break down into local residential lines run on every street. A transformer on the pole will serve several residences, breaking down the high voltage transmission lines into normal house entrance voltage. Entrance service will be 240V single phase, and modern houses will have anywhere from 100-200 amp service to a circuit breaker or fuse board at the central distribution point. Three wires are brought in by the power company to the house, two of which are the hot wires and one of which is grounded to the board. The serviceman has no control over the entering house voltage and therefore if this is not correct, his only recourse is to call the power company.

At the house service entrance, this power is broken down into various branch circuits to be distributed through the house. These branch circuits will be 120V single phase two wire circuits for use in lighting, plugs, appliances and a separate circuit for the furnace. The furnace should be the only appliance on that circuit and normal fusing is 15 amps.

Appliances drawing higher currents such as electric ranges, clothes dryers and air conditioners will have 240V service, which is obtained by tapping off each hot side of the entrance circuit. Fuse or circuit breaker size for these circuits will be in accordance with the current draw of the given appliance, in the case of an air conditioner this might be 30-40 amps per leg. The circuit breakers for each leg on a 240V circuit are mechanically interlocked so that if high current is experienced in one leg, the breaker will trip both legs of the supply service. **Figure G-1.**

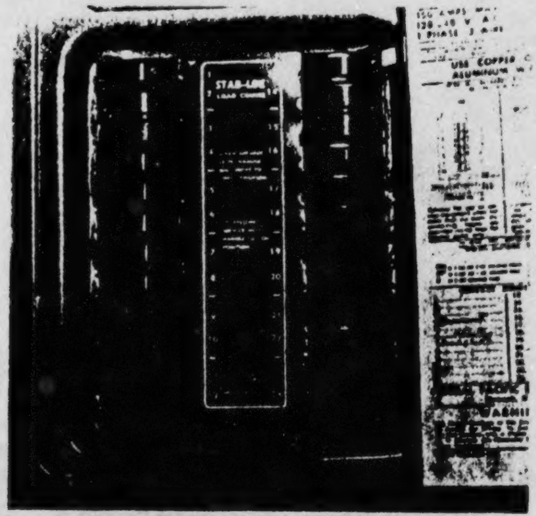


Figure G-1 Main Circuit Board

WIRE SIZE

Wire sizes and fusing for independent appliances will be determined by the manufacturer and called out on their wiring diagrams. Local codes should be examined to determine whether or not conduit is required in bringing the wire from the main circuit breaker to furnace or air conditioner. Some codes require conduit for parts of the circuit even on 120V. Specification sheets will give the minimum wire size and fuse size to meet the requirements of the National Electric Code, and this wire size is based on 125% of the full load current rating. The length of the wire run will also determine the wire size and Table 1 shows the maximum length of two wire runs for various wire sizes. This table is based on holding voltage drop to 3% at 240V. For other voltages the multipliers at the bottom should be used. If the required run is nearly equal to or somewhat more than the maximum run shown by the calculation of the table, then the next larger wire size should be used for a safety factor. It is always possible to use larger wire than called for on the specifications, but a smaller wire size should never be used as this will cause nuisance trips, affect the efficiency of operation and create a safety hazard. All replacement wire should be the same size and type as the original wire and be rated at 90^{o} - 105^{o}.

FUSES

Fuses should be time delay type fuse so that they will not blow during the initial starting current surge of the motor. All circuit breakers have a built-in time delay. Manufacturers specifications usually call out a maximum and a minimum fuse size for any given application, and the fuse selected should fall within this range. A fuse greater than the maximum will not protect the circuit and one smaller will result in nuisance trips when starting.

Waterproof strain relief and connectors should always be used at the entrance and exits to make-up boxes.

TABLE 1
MAXIMUM LENGTH OF TWO-WIRE RUN*

WIRE SIZE	AMPERES												
	5	10	15	20	25	30	35	40	45	50	55	70	80
14	274	137	91										
12		218	145	109									
10			230	173	138	115							
8					220	182	156	138					
6								219	193	175	159		
4									309	278	253	199	
3										350	319	250	219
2											402	316	276
1												399	349
0												502	439
00													560

*To limit voltage drop to 3% at 240V. For other voltages use the following multipliers:

110V	0.458
115V	0.479
120V	0.50
125V	0.521
220V	0.917
230V	0.966
250V	1.042

EXAMPLE: Find maximum run for #10 wire carrying 30 amp at 120V...... 115 x 0.5 = 57 ft.

NOTE: If the required length of run is nearly equal to, or even somewhat more than, the maximum run shown for a given wire size - select the next larger wire. This will provide a margin of safety. The recommended limit on voltage drop is 3 per cent. Something less than the maximum is preferable.

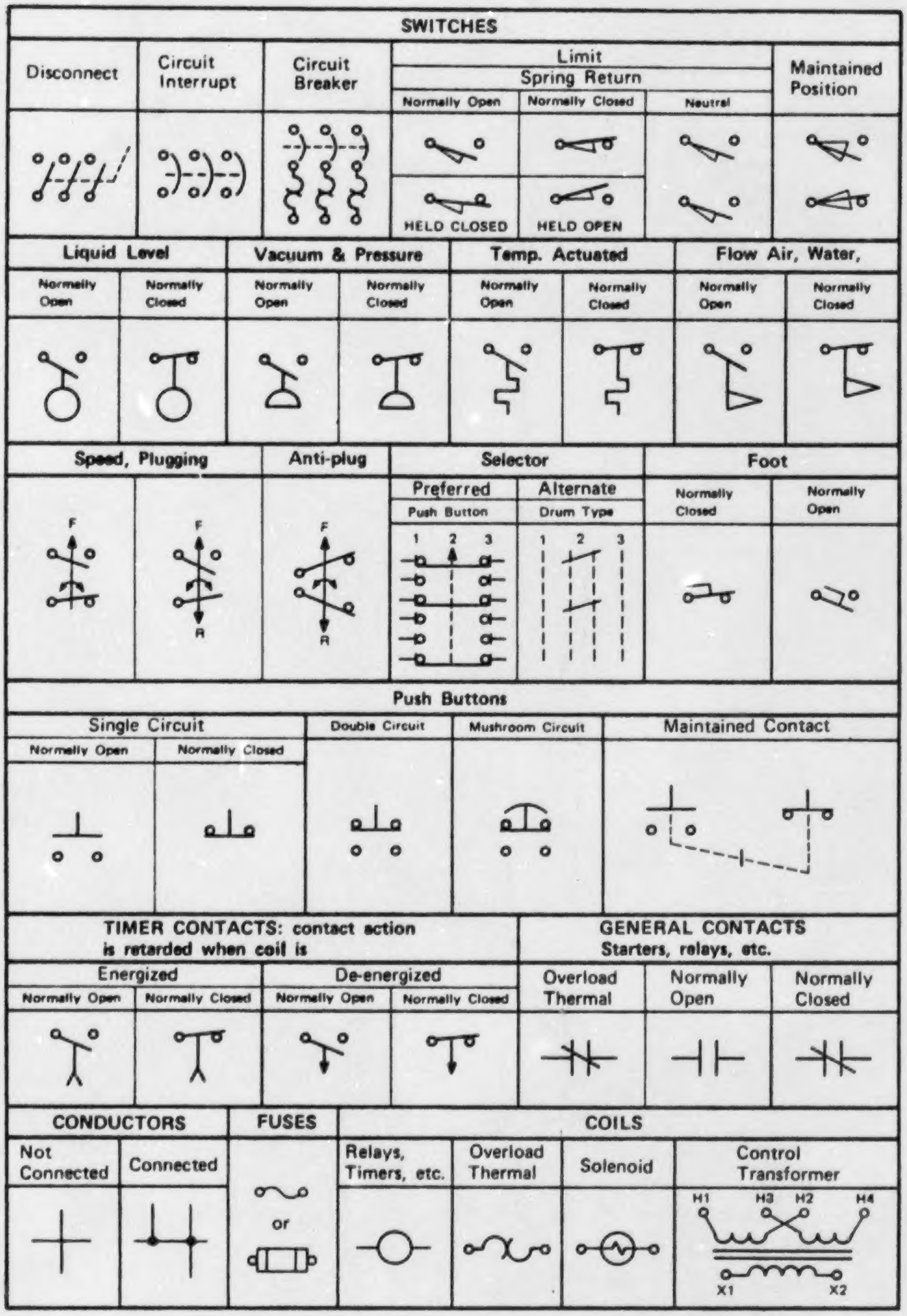

SWITCHES
Disconnect
Circuit Interrupt
Circuit Breaker
Limit
Spring Return
Normally Open
Normally Closed
Neutral
Maintained Position
HELD CLOSED
HELD OPEN
Liquid Level
Vacuum & Pressure
Temp. Actuated
Flow Air, Water,
Normally Open
Normally Closed
Normally Open
Normally Closed
Normally Open
Normally Closed
Normally Open
Normally Closed
Speed, Plugging
Anti-plug
Selector
Foot
F
R
Preferred
Push Button
Alternate
Drum Type
1 2 3
1 2 3
Normally Closed
Normally Open
Push Buttons
Single Circuit
Normally Open
Normally Closed
Double Circuit
Mushroom Circuit
Maintained Contact
TIMER CONTACTS: contact action is retarded when coil is
Energized
De-energized
Normally Open
Normally Closed
Normally Open
Normally Closed
GENERAL CONTACTS Starters, relays, etc.
Overload Thermal
Normally Open
Normally Closed
CONDUCTORS
Not Connected
Connected
FUSES
or
COILS
Relays, Timers, etc.
Overload Thermal
Solenoid
Control Transformer
H1
H3
H2
H4
X1
X2

Fig. 18-1. Graphic electrical symbols.

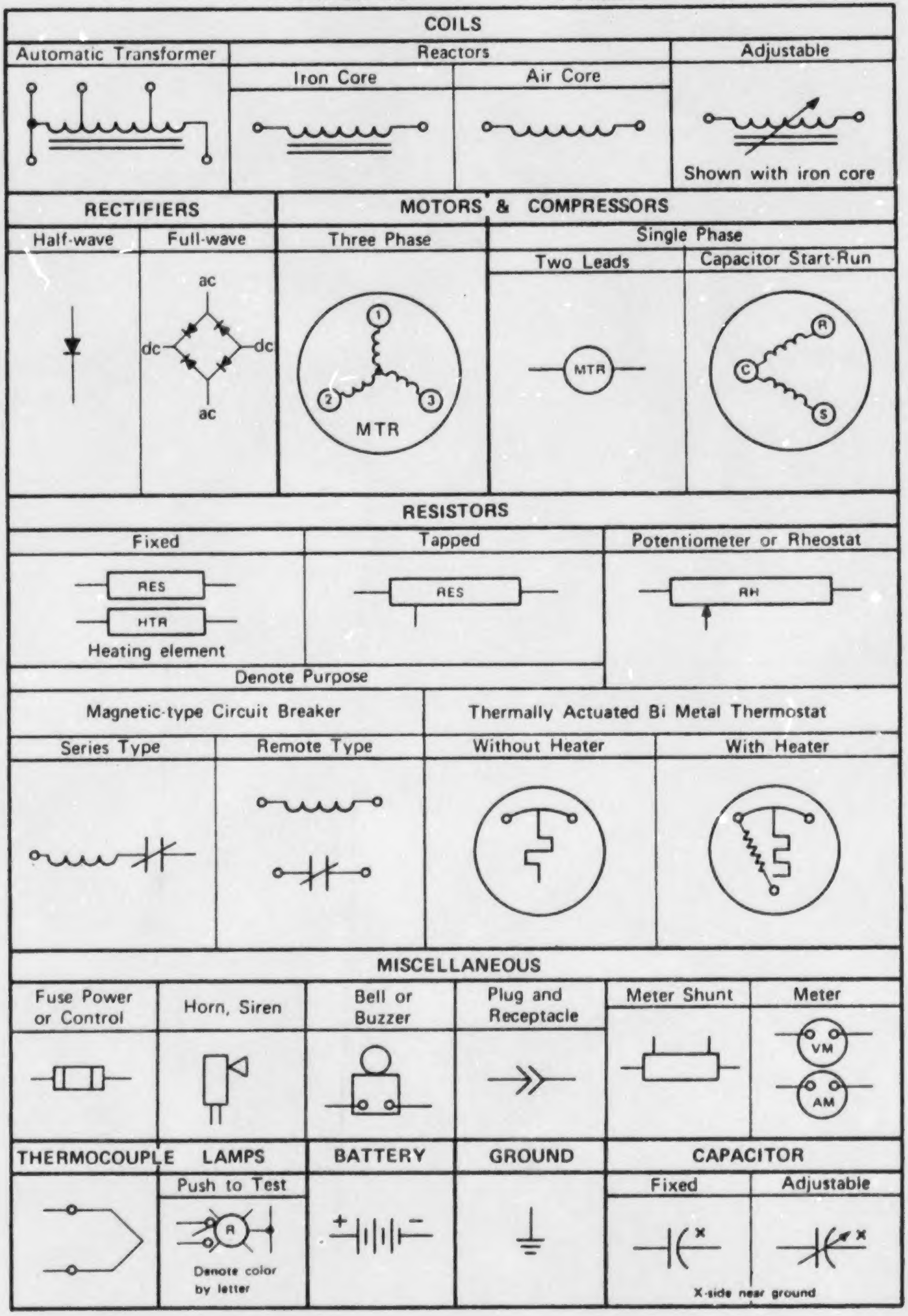

COILS
Automatic Transformer
Reactors
Iron Core
Air Core
Adjustable
Shown with iron core
RECTIFIERS
Half-wave
Full-wave
ac
dc
dc
ac
MOTORS & COMPRESSORS
Three Phase
1
2
3
MTR
Single Phase
Two Leads
MTR
Capacitor Start-Run
R
C
S
RESISTORS
Fixed
RES
HTR
Heating element
Tapped
RES
Potentiometer or Rheostat
RH
Denote Purpose
Magnetic-type Circuit Breaker
Series Type
Remote Type
Thermally Actuated Bi Metal Thermostat
Without Heater
With Heater
MISCELLANEOUS
Fuse Power or Control
Horn, Siren
Bell or Buzzer
Plug and Receptacle
Meter Shunt
Meter
VM
AM
THERMOCOUPLE
LAMPS
Push to Test
R
Denote color by letter
BATTERY
+
−
GROUND
CAPACITOR
Fixed
Adjustable
x
x
X-side near ground

Fig. 18-1 (Cont.). Electrical diagrams.

FUSES AND CIRCUIT BREAKERS

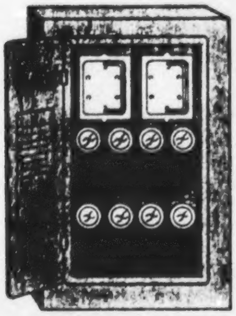
The Job They Do

Fuses and circuit breakers might be called the watchmen of your electrical system. When a fuse blows or a circuit breaker trips, it is telling you that something is wrong. **What** is wrong may be two bare electric wires touching because of worn insulation; too many applicances on the same circuit; or an overloaded motor. It makes no sense to replace a blown fuse or reset a circuit breaker unless you have found and corrected the cause of the trouble. If the condition exists when you make the replacement, you will blow another fuse or trip a circuit breaker again.

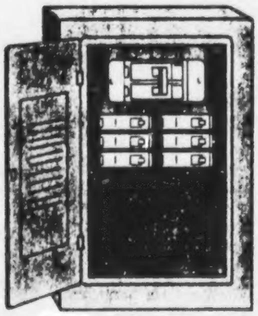
The most common cause of fuse-blowing is too many appliances on the same circuit. If a fuse blows when you push down the toaster handle, there is a good chance that you may be operating, say, a broiler or an electric iron on the same circuit. If you are, unplug the iron or broiler, and then replace the fuse or reset the circuit breaker.

A fuse that has been blown by a short circuit will usually have a blackened or discolored mica window. A fuse that has blown because of an overload will usually show a clear window, but there will be a break in the flat metal strip. The circuit breaker just flips to the "tripped" (off) position when there is an overload or short circuit.

It is practical to keep spare fuses handy near the fuse box. When you replace a fuse, be sure that the new one is of the same capacity. In other words, if you blow a 15 ampere fuse, replace it with a 15 ampere fuse, never a 20 or 25.

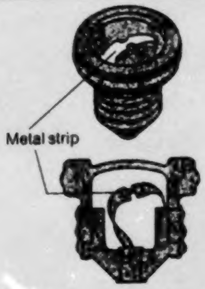


Fuse box with the main disconnect at top

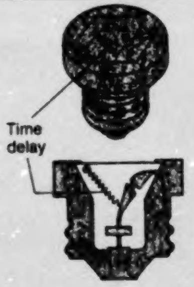


Circuit breaker panel with main disconnect

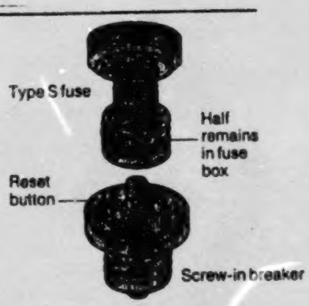
TYPES OF FUSES AND CIRCUIT BREAKERS


Metal strip

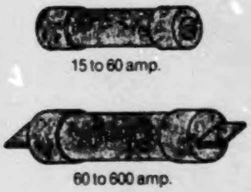
Plug fuse has base similar to light bulb. Metal strip shows through mica window if fuse is good. Blackened window or break in strip means blown fuse.



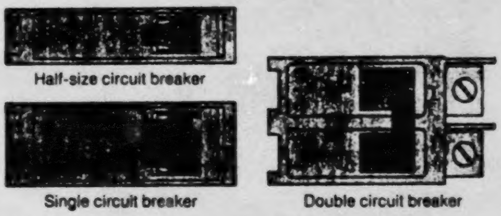
Fusetron fuse is like plug fuse except for a spring-loaded metal strip that allows a temporary overload. Used mainly on circuits for washers, large power tools.


Type S fuse
Half remains in fuse box
Reset button
Screw-in breaker

Type S fuse prevents use of wrong size fuse. Each side has a different thread. **Screw-in breaker** replaces fuse. When blown, button pops out. Push to reset.


15 to 60 amp.
60 to 600 amp.

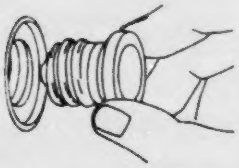
Cartridge fuses: Round type, top, is made up to 60-amp. capacity; bottom type, with knife-edge contacts, from 60 amp. up. Use fuse puller to remove safely.


Half-size circuit breaker
Single circuit breaker
Double circuit breaker

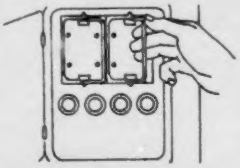
Circuit breakers do same job as fuses, but are not replaced when they "blow." Instead, toggle switch is pushed to "reset" or "on." Made in same capacities as fuses. Double circuit breaker with connecting bar is used to protect 240-volt circuits; two-in-one circuit breaker has two breakers in the space of one.

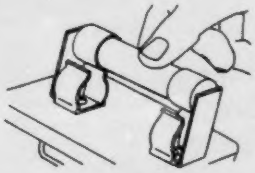
How To Replace A Blown Fuse

Remove the fuse by turning it counterclockwise (first shut off the main switch). If it is a 15 ampere fuse, make sure the replacement is the same. Pull a cartridge-type fuse straight out. Large ones are best handled with a fuse puller. To "replace"a tripped circuit breaker, push the toggle handle to "reset" or "on". Always be sure your feet are on a dry surface and keep one hand at your side or in your pocket.

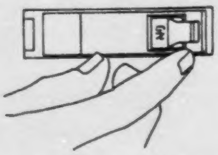


Remove blown fuse by turning counterclockwise. Be sure new one has same capacity.





If fuse box has main disconnect of type above, pull it out to get at main fuses. This will expose cartridge-type fuses. Pull straight out; put in new fuse of same capacity, type.



Tripped circuit breaker: Easy to "replace." Just push switch to "reset" or "on."

Electrical Terms and Their Meaning

In order for electricity to travel through wiring, it has to be under pressure - much the same way water is under pressure in your plumbing system. This electrical pressure is measured in volts or voltage. Modern homes receive 240 volts of electrical power. This power enters the home through an electrical service entrance and passes through a meter where the amount that the household uses is measured and distributed throughout the house. Most appliances operate on 120 volt current; heavy-duty appliances such as an electric range or oven, clothes washer or dryer require 240 volts.

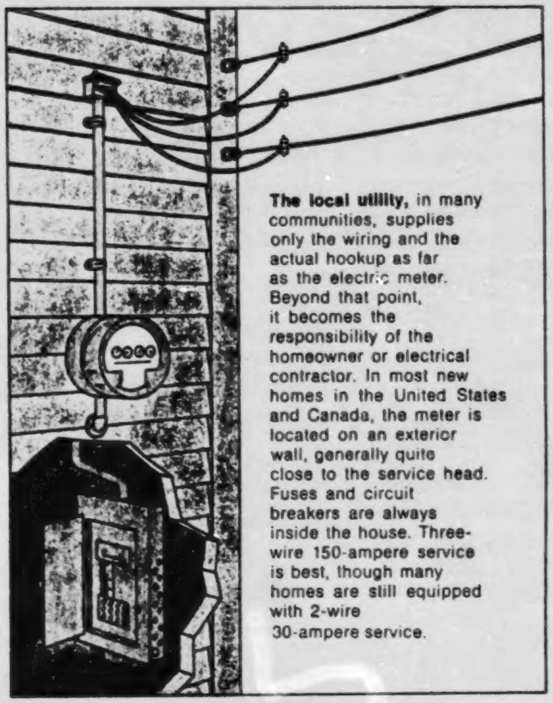
Current, or rate at thich electricity is delivered to an appliance, is measured in amperes. It is limited by the diameter of the wire it must flow through. Just as a larger diameter pipe can deliver more gallons per minute, a larger diameter wire can conduct more amperes. Since excess current causes a wire to overheat, fuse size must be matched to wire size so that if necessary the fuse will blow before the wire becomes a fire hazard.

The wiring that travels through the walls and ceilings of a house is divided into circuits. Each circuit connects with a series of wall outlets and switches. Each heavy-duty appliance has its own separate circuit. Every household circuit is protected by a fuse or a circuit breaker. These devices break (or interrupt) the circuit when it is overloaded.

The number of electrical circuits in a house determines how many electrical appliances you can use conveniently and safely. If your home is over 20 years old and has never been rewired, it undoubtedly needs improvements in its wiring system.

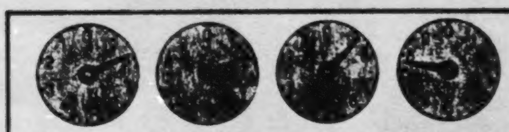
Hookup From Power Lines

Never attempt to work on the electric power hookup entering the house. These wires carry high voltage and are dangerous. Should they become damaged or worn, call your power company to make repairs.



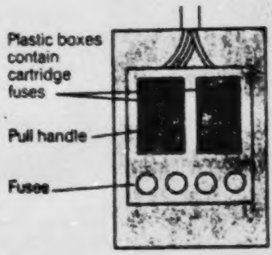
The local utility, in many communities, supplies only the wiring and the actual hookup as far as the electric meter. Beyond that point, it becomes the responsibility of the homeowner or electrical contractor. In most new homes in the United States and Canada, the meter is located on an exterior wall, generally quite close to the service head. Fuses and circuit breakers are always inside the house. Three-wire 150-ampere service is best, though many homes are still equipped with 2-wire 30-ampere service.

How To Read A Meter

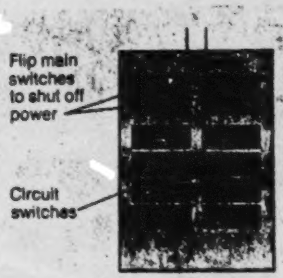


When the needle is between two numbers, always read the lower number. The dials in this illustration, for example, read 8187. The needle for each dial must have reached a number before you read that number. Note that the needle for the second dial from the left has passed the 1 mark but has not reached the 2.

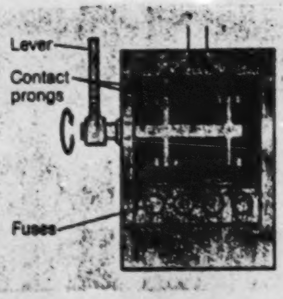
How To Shut Off Main Power



Cartridge-type boxes: The main power is shut off by pulling out the plastic cartridges. Removal of both cartridges shuts off all household power.



Circuit breaker boxes have one or two large switches that control household power. These merely have to be pushed to the "off" position.



Lever-type switches are usually found in older wiring installations as the main power switch. Lifting (or pulling) the lever to the "off" position will cut the main power supply.

Is The Wiring Adequate?

Your home needs more wiring if it exhibits any of the following symptoms: Fuses or circuit breakers blow or trip often; lights flicker when appliances are turned on; appliances do not operate at full power; TV image shrinks when a heavy appliance is on; you use too many extension cords. Most people can manage with their present wiring only because not all circuits are in use at the same time.

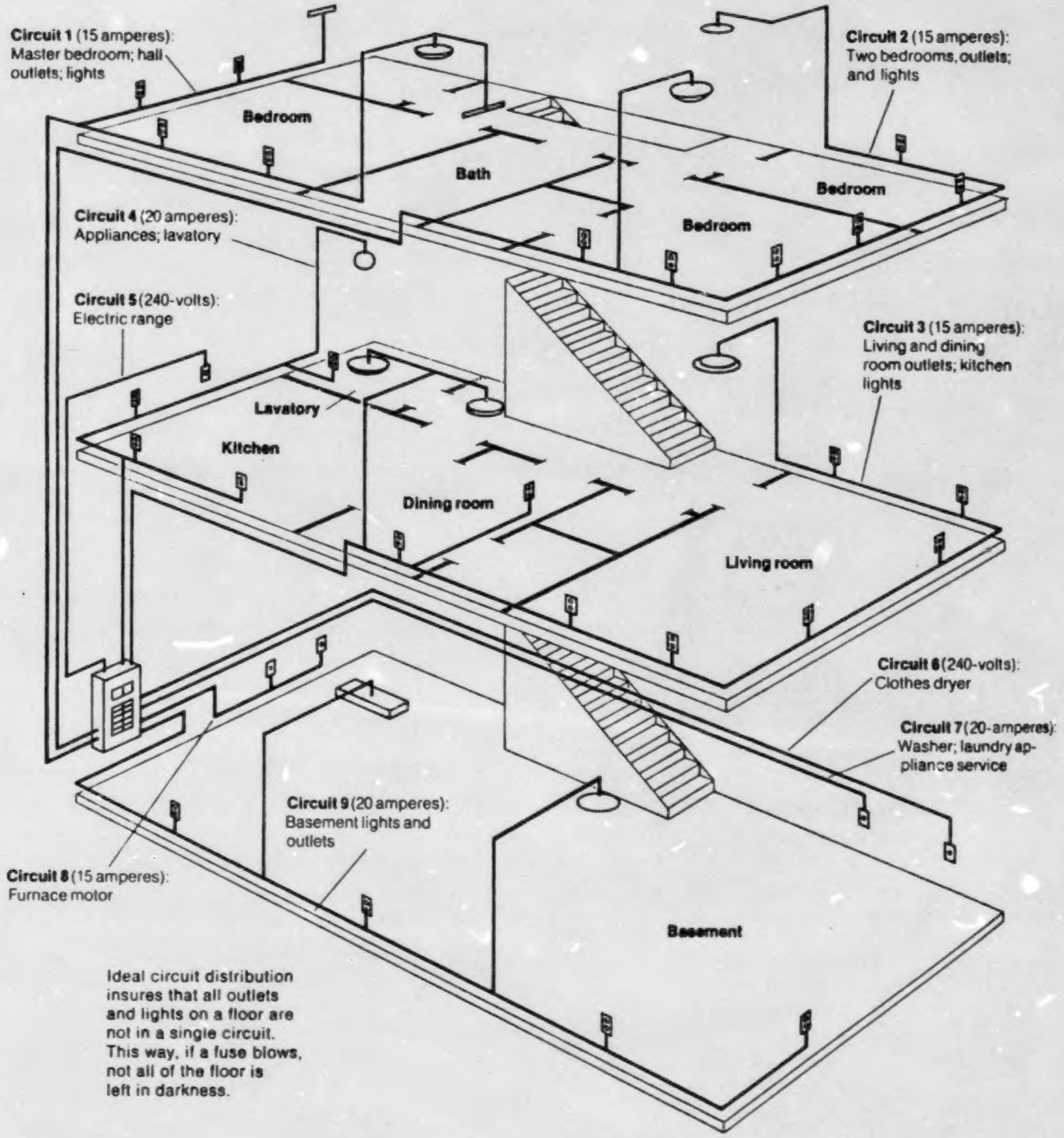
List the watts used by all appliances that would normally be operated simultaneously. Be sure to include light bulbs and fluorescent tubes. Appliance wattage usually appears on the nameplate. If any of your nameplates are missing or illegible, check the appliance's needs in the chart below. Add up the wattage of all lights and appliances on each 110 volt circuit and check the fuses. If the result is more than 1,650 on a circuit with a 15 ampere fuse, or 2,200 for 20 ampere fuse, you may blow the fuse when all appliances are on. To avoid trouble, plug one or more of the items into another circuit. Circuits carrying 240 volts are almost always used for a single appliance; check its amperage against fuses.

REPRESENTATIVE WATTAGE RATINGS

Item	Watts	Item	Watts
Air conditioner (room)	1350	Lamp (floor)	300
Air conditioning		Lamp (outdoor)	100
(central)	5000	Lamps	60–150
Blender	250	Lathe	300
Can opener	150	Mixer	150
Coffeemaker	600	Radio	50
Dishwasher	1800	Range (electric)	8000 to
Drill press	300		16000
Dryer	6000	Refrigerator	250
Fan	75	Roaster	1380
Food warmer	500	Rotisserie	1400
Freezer	350	Saw	570
Fryer	1320	Shaver	10
Furnace	250	Stereo hi-fi	300
Garbage disposer	900	Sump pump	300
Grill	1300	Sun lamp	275
Heater (hot water)	2500	Television	300
Heater (room)	1600	Toaster	1100
Hot plate (2-burner)	1650	Vacuum cleaner	400
Iron (hand)	1000	Ventilator	100
Ironer	1650	Washer	350

To obtain amperes, divide watts by volts. Use 110 for the latter—it is close enough for practical purposes. For 220-volt appliances, divide by 220.

Balanced circuits are important


Bedroom
Bath
Bedroom
Bedroom
Lavatory
Kitchen
Dining room
Living room
Basement

Circuit 1 (15 amperes): Master bedroom; hall outlets; lights

Circuit 2 (15 amperes): Two bedrooms, outlets; and lights

Circuit 3 (15 amperes): Living and dining room outlets; kitchen lights

Circuit 4 (20 amperes): Appliances; lavatory

Circuit 5 (240-volts): Electric range

Circuit 6 (240-volts): Clothes dryer

Circuit 7 (20-amperes): Washer; laundry appliance service

Circuit 8 (15 amperes): Furnace motor

Circuit 9 (20 amperes): Basement lights and outlets

Ideal circuit distribution insures that all outlets and lights on a floor are not in a single circuit. This way, if a fuse blows, not all of the floor is left in darkness.

Power Requirements

The first step is to learn something about local codes from your city or town building inspector. In some areas you are not permitted to do your own wiring. Many communities will permit you to install new circuits up to the service entrance panel, but insist that a licensed electrician complete the final hookup. This is a wise practice, since the high cost of additoonal circuits is in the routing of the wire. Most electricians will be happy to inspect your work before making final connections for only a fraction of what they would charge for the entire job.

The code determines what type of wire you must use. Some areas use "Romex" (wire with nonmetallic sheathing); others use "BX" (armored cable). Wire size is important. Wires are rated by numbers, the lowest numbers indicating larger diameter wire. Number 12 wire is generally recommended throughout the home. Number 14 wire can be used, however, for 15 ampere circuits.

Part of your planning includes checking the existing electrical service panel to see if there is room for new circuits. Be sure to check also with the local utility company to be certain that the lines leading into your home have the capacity to deliver the extra power the new circuits would requre.

Refer to the electrical service panel illustrated here for help in determing what circuits should feed various appliances and lighting needs in an efficient circuitry plan. Try to plan circuits so that lighting is kept separate from heavy-duty circuits such as those in the kitchen and laundry areas.

Installing an "Add-on" Panel

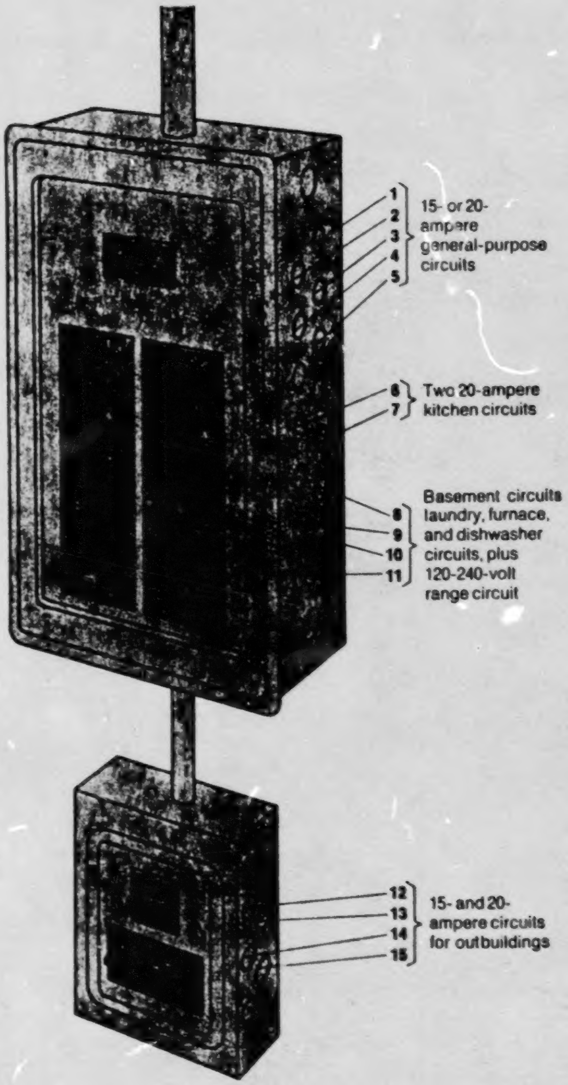
These units do the job of a small electrical service panel. The power from the main service entrance flows into the add-on panel and is distributed to the supplementary circuits.

Most service entrance panels have two power takeoff screws located between the two left and the two right plug fuses. Wires leading to the add-on panel are connected to these terminals as shown. The two black wires go to the terminals and the white wire goes to the neutral bar.

At the add-on panel, both black wires are joined to the fuses' screw terminals and the white to the neutral bar. New circuits are then connected.

HOW TO AVOID DANGER

Working with electricity is not hazardous as long as you obey strict safety rules. Always shut off or disconnect power before handling wires. If you are working on the electrical service entrance, do not stand on a damp floor. Protect yourself by wearing rubber gloves and rubbers, and stand on a rubber mat or a piece of dry wood. If you doubt your skill, call in a licensed electrician. Use only materials approved by a testing organization such as Underwriters' **Laboratories**.


1
2
3
4
5
15- or 20-ampere general-purpose circuits
6
7
Two 20-ampere kitchen circuits
Basement circuits laundry, furnace, and dishwasher circuits, plus 120-240-volt range circuit
8
9
10
11
12
13
14
15
15- and 20-ampere circuits for outbuildings

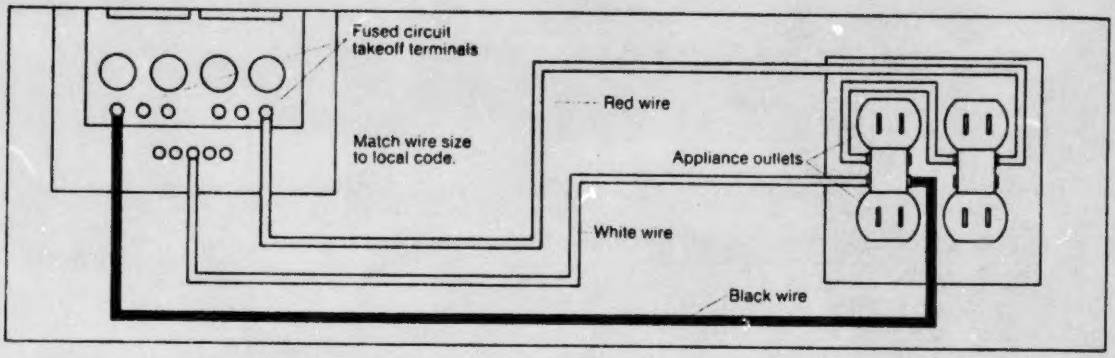
General-purpose circuits of 15 and 20 amperes take care of all lamps (ceiling, wall, bed, desk, drop lights, etc.), radio and television sets, outlets for vacuum cleaner and small appliances drawing a simultaneous total of under 1750 watts for a 15-amp. fuse, or 2300 watts for a 20-amp. fuse.

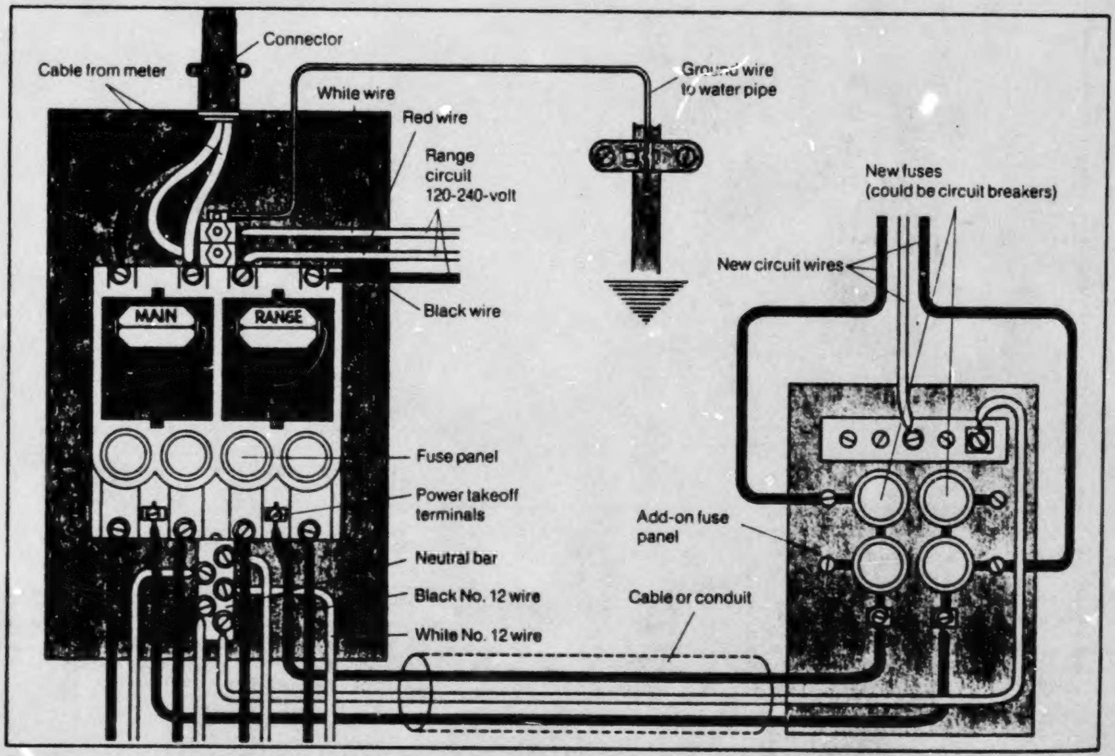
If a room has no fixed ceiling light, at least one wall outlet must be wired into the wall switch.

Two or more 20-ampere circuits for fryer, broiler, grill, iron, toaster, blender, food mixer, and similar kitchen appliances. Since more than two kitchen appliances are seldom used at the same time, a separate circuit for each appliance (except refrigerator) is really not necessary.

Separate basement circuits of 20 amperes serve laundry appliances and workshop power tools. A furnace is always on a separate circuit with no other outlets or lights on it. Room air conditioners of more than 1500 watts, hot-water heater, electric range, and clothes dryer require individual 240-volt circuits.

Service to an outbuilding such as a barn, guest house, or workshop should be on a separate power take-off from the main entrance panel. It should have its own disconnect switch. Four 15- or 20-ampere circuits are generally sufficient.


Fused circuit takeoff terminals
Red wire
Match wire size to local code.
Appliance outlets
White wire
Black wire


Connector
Cable from meter
White wire
Red wire
Ground wire to water pipe
Range circuit 120-240-volt
MAIN
RANGE
Black wire
New fuses (could be circuit breakers)
New circuit wires
Fuse panel
Power takeoff terminals
Add-on fuse panel
Neutral bar
Black No. 12 wire
Cable or conduit
White No. 12 wire

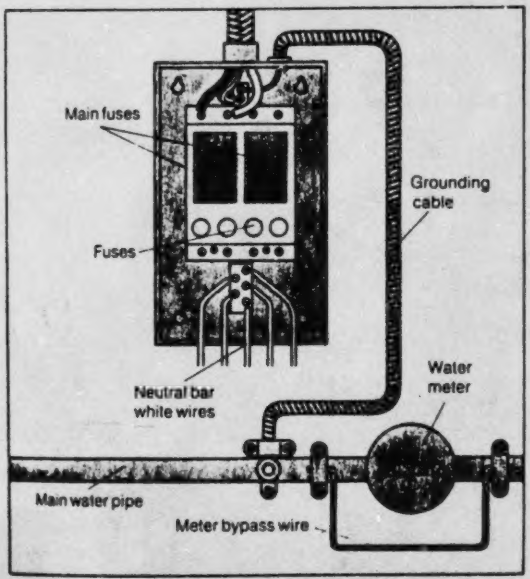
Three-wire electrical cable in older homes will have two black wires and one white one. In more recent construction, this has changed to one black, one red, and one white. Present electrical codes call for a fourth wire, which is a ground. This ground wire is bare metal. To avoid confusion, ground wires have been left out of these illustrations.

Grounded Wiring

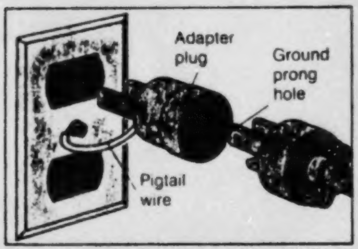
Household wiring is color coded. In 120 volt circuits one wire, called the neutral wire, is white; the other, the hot wire, is black or another color, but never white. Both are live wires. In circuits carrying 240 volts only, one wire is usually black and the other another color, but neither should be white. In 3-wire circuits carrying both voltages one wire is white, the other two black or colored. You get 120 volts by connecting the white wire and a colored wire to an outlet, 240 volts by connecting the two colored wires to an outlet.

The fuse or circuit breaker panel of your home is grounded; therefore, there is a wire connecting the service panel to a rod which is driven into the earth. In residential areas, this gound wire is usually attached to the water-supply pipe which leads into the ground. The white neutral wires of the various branch circuits throughout the house are also connected to grounded terminals in the service panel. This is necessary for a number of reasons, such as reduction of the possible effects of lightning.

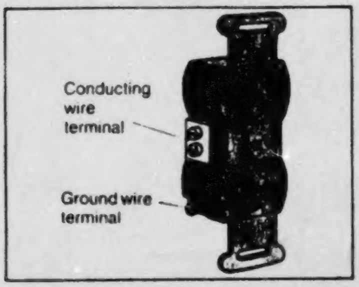
Grounded wiring systems are those in which all metal outlet and switch boxes, cable armor, and exposed metal parts of the wiring system are connected back to grounding terminals in the fuse or circuit breaker. Grounding terminals of grounded receptacles are connected to the box by a jumper wire or other means. A 3-prong appliance cord continues the grounding to an appliance or power tool. If a loose wire touches the frame of such an appliance or tool, the grounding wire will protect the user from shock and may cause a fuse to blow or a circuit breaker to trip. Appliances or tools that do not have such protection can be dangerous - you could get a shock of something should go wrong with the internal wiring. Check your system for grounding by seeing what type of wiring is installed in your home. If the wiring is of nonmetallic cable, that cable should have a third wire (which has no plastic sheathing) that is connected directly to the electrical outlet boxes. Metal conduit also serves as a grounding conductor.



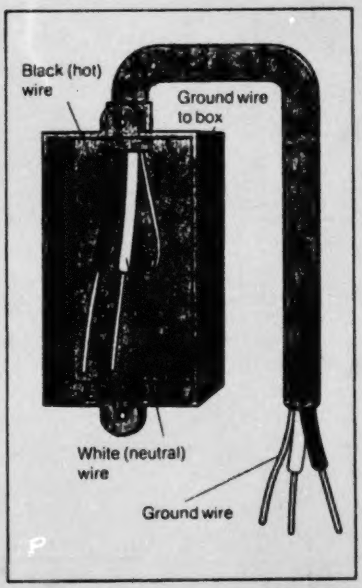
Electric service entrance is grounded to metal water-supply pipe or to a special metal rod driven into the earth.


Adapter plug
Ground prong hole
Pigtail wire

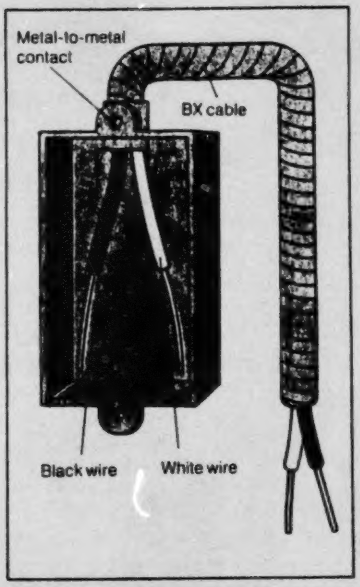
Fit 3-wire adapter plugs with pigtail attached to receptacle plate.


Conducting wire terminal
Ground wire terminal

Three-hole receptacle has a green terminal screw for the grounding wire.


Black (hot) wire
Ground wire to box
White (neutral) wire
Ground wire

Copper ground wire of nonmetallic cable connects directly to outlet box.


Metal-to-metal contact
BX cable
Black wire
White wire

Metallic sheathing of BX cable acts as ground conductor in older homes.

ELECTRICAL TOOLS

Important: Unplug appliances you are working on. If changing switches or electrical wiring, remove the fuses or shut off the circuit breakers that supply power to the circuits you are working on.

You probably already have most of the tools that are required for minor electrical repairs or wiring. These include screwdrivers, knife, ruler, hammer, saw, chisel, brace and bit, electrician's pliers, metal snips, and locking pliers.

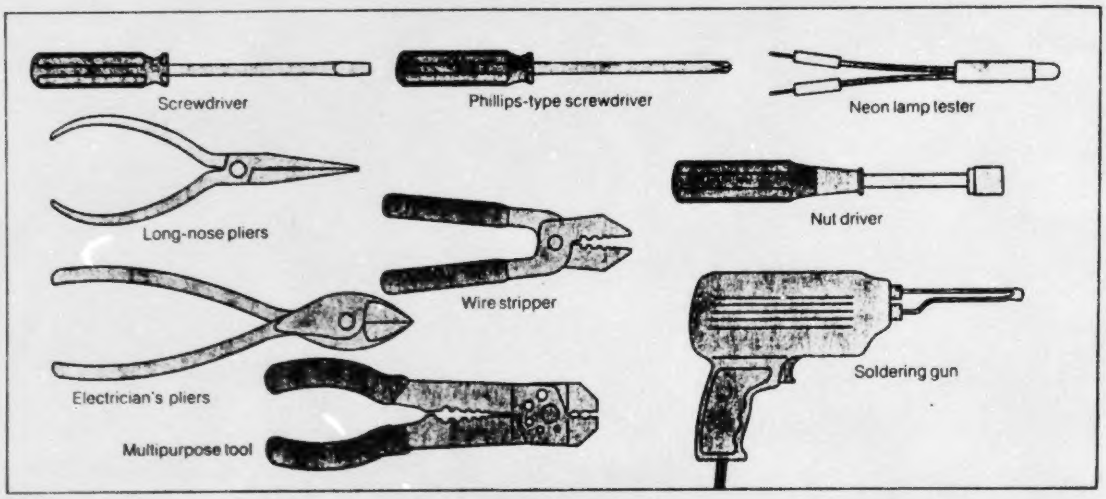
More complicated jobs can be simplified with inexpensive specialized tools, such as screwdrivers with a device on the end that holds small screws for insertion in inaccessible areas, such as electrical boxes; Phillips-type screwdrivers for the crossslotted screws often used in appliances; nut drivers that have a socket on their end to drive or remove nuts in areas in which a wrench would not fit.

Another necessity is a neon lamp tester, a small light with two wires that are inserted into an electrical outlet to see whether power is present.

Long-nose pliers are used to hold screws, nuts, and similar small hardware so that you can insert or remove them in hard-to-reach places inside walls or appliances. They are equipped with side cutters which can be used for cutting wires.

Wire strippers slice neatly through the insulation covering a wire and remove it without disturbing the wire iteslf. This is a necessary step prior to making connections with new wire. There is also a multipurpose tool that cuts and strips wire and can crimp terminals (fasteners) to the ends of a wire, joining them without the use of solder.

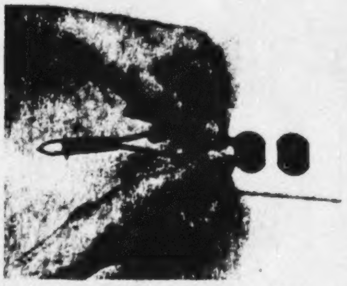
In electrical work, a soldering gun is a better choice than a soldering iron because it heats faster and has an easily held pistol grip.



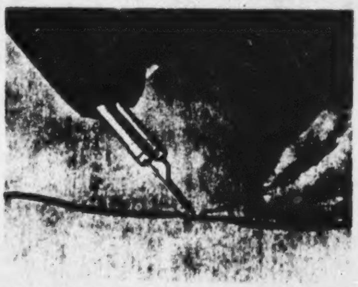
Side cutters of electrician's pliers cut through wire. Can be used as strippers.

Crimping of solderless terminals joins wires without the use of solder.

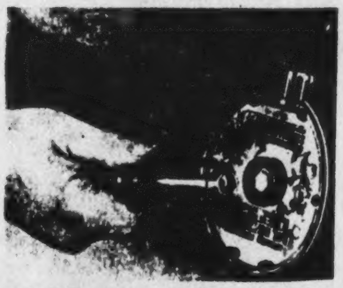
Stripper removes outer covering of wire, leaving the wire itself untouched.



Test lamp inserted in outlet lights up, signaling presence of electricity.



Soldering gun melts solder to form permanent electrical connections.



Nut driver reaches nuts in cramped areas where wrenches do not fit.

ELECTRICAL POWER CABLES

Length is important. A longer cord wastes current. If it is too long, the drop in current can reduce an appliance's efficiency. The table below recommends suitable extension cord wire lengths and diameters for various electrical loads.

Selecting the proper length

Length	**To 7 amp.**	**7-10 amp.**	**10-15 amp.**
To 25 ft.	No. 18	No. 16	No. 14
To 50 ft.	No. 16	No. 14	No. 12
To 100 ft.	No. 14	No. 12	No. 10

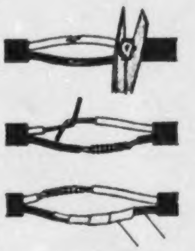
Wire diameter to use (p. 261)

Remove extension cords from an outlet by grasping the plug body. Otherwise, the wires may tear loose, resulting in a shock or short circuit.

Three-wire extension cords are used for electric power tools and outdoor appliances. The third wire is a grounding wire; plug this type of cord into a grounded outlet or ground it with a suitable adapter plug. Use only 3-wire extensions for tools and appliances that have 3-wire cords.

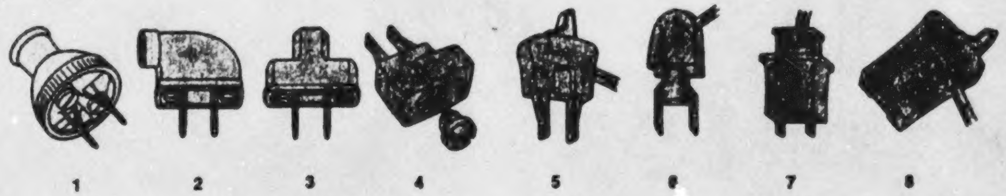
Most cords are sheathed in plastic that can take rugged use. Rubber-sheather cords are more flexible and easier to store.

Splicing cord wires



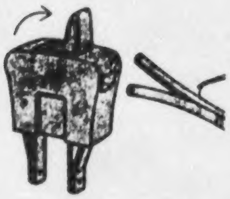
1. Cut away damaged insulation with scissors. Cut both wires in half with wire cutters. Strip 1 in. of insulation from wires with wire stripper or sharp knife. **2.** Twist ends of both wires. **3.** Wrap each wire with tape, then wrap wires together. Overlap tape onto cord. Splicing is an emergency repair not approved by electrical code. **Do not splice house wiring.**

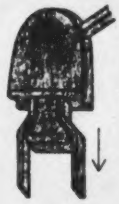
Types of plugs

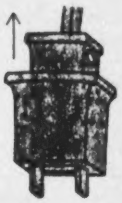


Plug replacement is easy with these readily available plugs. In addition to the new plug, you'll need wire cutters, a screwdriver with a small tip, and a sharp paring knife. Replacement of round-wire plugs (Nos. 1–3) and flat-wire plugs (Nos. 5–8) is illustrated below. For plug No. 4, loosen screw, slip wire into casing, and tighten screw.

Flat-wire plugs

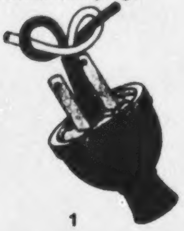

1

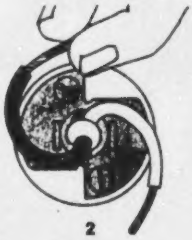

2

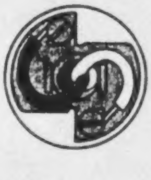

3

1. Lift top clamp. Slit cord ¼ in. between wires. Push cord into plug; close clamp. **2.** Grasp prongs and pull firmly to remove from casing. Spread prongs. Insert wires through plug and into terminal. Close prongs and place securely in casing. **3.** Remove casing. Insert wire and push through plug. Replace casing. **Flat-wire plugs are easiest to replace because no wire stripping is involved.**

Round-wire plugs

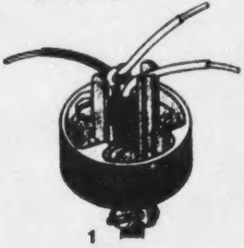

1

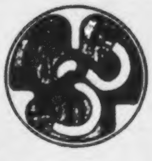

2

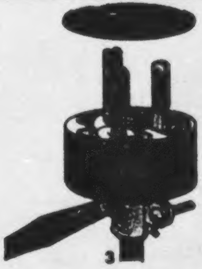

3

1. Loop both wires exactly as shown to tie an "Underwriters" knot. Pull the knot down into the plug casing between the prongs. This knot is important because it protects the wires from strain should the plug be pulled from a socket by the cord. **2.** Strip ½ in. of sheathing from each wire. Twist wires in clockwise direction. **3.** Loop wires around screws in clockwise direction. Tighten screws and clip off any excess wire. Be sure that no strands from the black wire are in contact with those of the white wire.

3-prong plugs

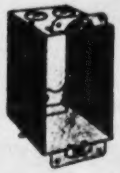

1


2

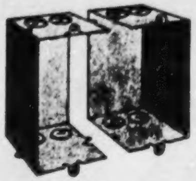

3

1. Loop all three wires together if plug space permits. If space does not permit, tie black and white wires in "Underwriters" knot (as above) and leave third wire free. **2.** Strip plastic sheathing from all three wires. Twist wire strands clockwise. Loop wires clockwise around screws. (Wires must not be allowed to touch each other.) **3.** Tighten both outside screws to secure cord to plug. Slip protective cover over prongs and push down to cover exposed wires; this is an important safety precaution.

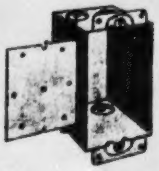
Wall boxes



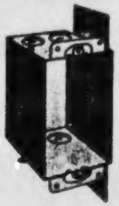
1. Metal box is flush-mounted in lath wall. Surface-mounted also available



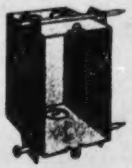
2. Several metal boxes are joined together by removing their side plates.



3. Metal box with a flange is nailed to the front or rear of stud in drywall.

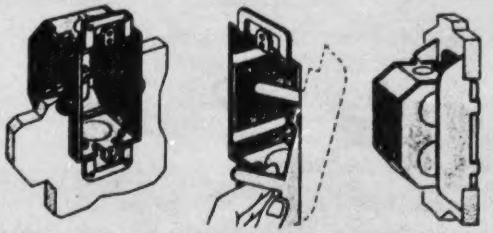


4. The flange on this box can be screwed to the side of stud in drywall



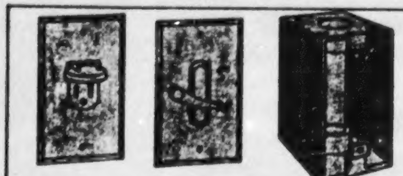
5. Small side flanges of this box can be nailed to side of stud in drywall.

Wall box accessories

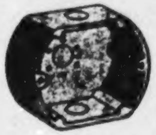


Mount wall boxes between studs in drywall with box clamps, left, which grip rear side of wall as side screws are tightened. Or use metal supports, right, that slip in hole; projecting tabs are bent into box.

Boxes for damp locations

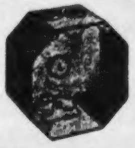


Weatherproof outlets, switches, and boxes for outdoor installation. Single or multiple outlets have snap covers. Both single and three-way switches are available.

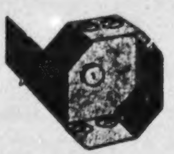


Bakelite wall and ceiling boxes used in damp areas cannot be ganged together.

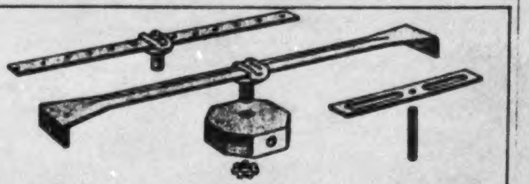
Ceiling boxes and accessories



Metal boxes for ceiling mounting are made square, octagonal, and round.

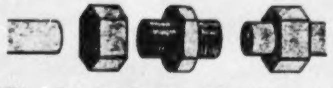


Flange on this metal box permits it to be nailed or screwed to joists in a ceiling.

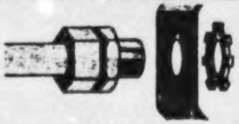


Adjustable hangers, left, permit ceiling boxes to be fastened between ceiling beams. Shallow box hangers, right, rest on ceiling laths.

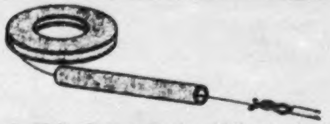
Thin-walled conduit and accessories



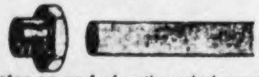
Fiber ring inside nut clamps conduit pushed into it. Tightening coupling joint secures both pieces.



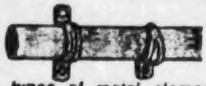
Fiber ring inside this nut clamps conduit and coupling joint. Coupling joint is secured to box with locknut.



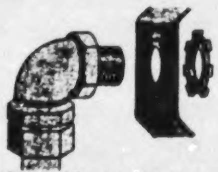
A 50-ft. fish tape (p. 264) attached to the wire is used to pull the wire through a conduit or through a wall.



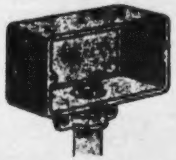
Adapter on end of unthreaded conduit attaches conduit to threaded box.



Various types of metal clamps and screws attach the conduit to a wall.

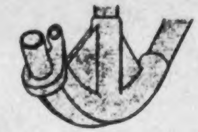


Fiber ring inside nut attaches conduit to right-angle adapter. Adapter is held to the box with a locknut.

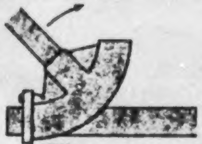


Rigid threaded conduit inserted into neck of threaded box is securely attached to the box with metal clamps.

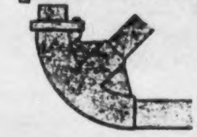
Bending conduit with a hickey



Make bends in conduit with an electrician's hickey. The total bend angles in a length of conduit between two boxes must not exceed 360°.

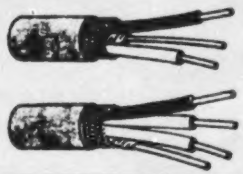


Hook bender over conduit with the inside of the grip hook at mark. Bend the conduit by pulling the handle back in the direction of the bend.

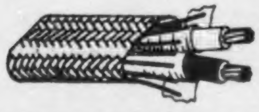


Placing a foot on a straight section of conduit makes bending easier. Check the bend occasionally to be sure that the angle is correct.

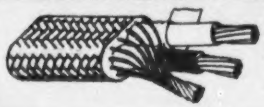
IV-S-433



Buying cable: Cable is classified according to the number of wires it contains and their size or gauge. Two-wire cable actually contains three wires: The black (hot) wire, the white (neutral) wire, and a third which is the ground wire. Similarly, 3-wire cable contains four wires: Black, white, and red (which is also a hot wire) and a ground wire.

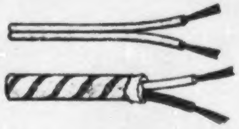


Service entrance cable: Used to transmit power to main entrance switch. Can be used indoors or outdoors. Also used to wire large appliances such as ranges and water heaters. Usually a 3-wire cable.

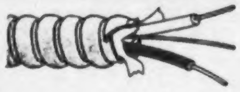


Nonmetallic sheathed cable: For indoor use. Has a moisture-resistant, flame-resistant covering. It is made with and without a ground wire. The wires are copper or aluminum. No. 6 and larger are stranded.

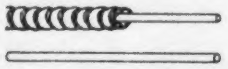
Underground feeder and branch circuit cable: Can be used underground, indoors or out. Does not require a conduit when buried. Resists water and corrosion.



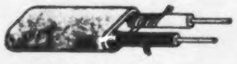
Extension and appliance cords: Come in light- and heavy-duty types. Lamps usually use plastic-covered types. Appliances and motors take heavier forms with wire size to suit the load. Extension cords are sold with connectors at each end.



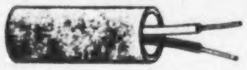
Armored BX cable: Used only in dry, indoor locations. Wires are copper; bare ground may be aluminum. Must be used with steel junction and switch boxes. Made in 2- and 3-wire types.



Ground wire: Used to ground an electrical system to a cold-water line or to a copper rod buried in the ground. Generally single-wire armored cable. Wire size depends on service wire size. Check local code.

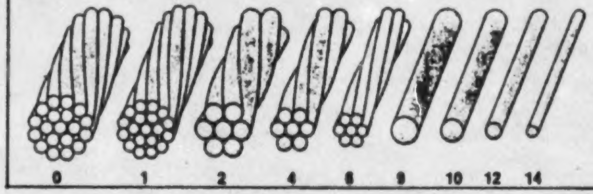


Lead-encased underground cable: Generally used to transmit power to outbuildings from main power source. Must be substituted for plastic-covered wire if local electrical code requires it.



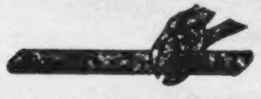
Thin-wall steel conduit: Required by some towns. Installed same way as piping; wires are pulled through afterward. Acts as its own grounding conductor. Made in 10-ft. lengths; joined by special connectors.

Wire sizes

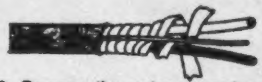


Wire sizes for residential wiring vary from No. 14, the smallest permitted, to No. 0. (Sizes to 0000 available for special work.) The smaller the number, the larger the size. The wires shown are actual sizes. No. 6 and larger wires are stranded.

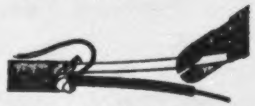
Installing nonmetallic cable



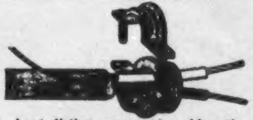
1. Strip off about 6 in. of the cable covering. Be careful not to cut insulation.



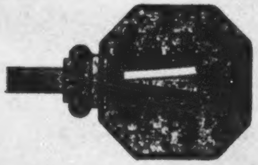
2. Remove the outer wrapping from each of the wires. Insulation is inside wrapping.



3. The next step is to strip off insulation to expose about 1 in. of the solid copper wire.

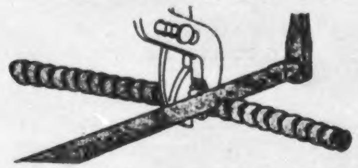


4. Install the connector. Use the kind made for nonmetallic cable with two locking bolts.

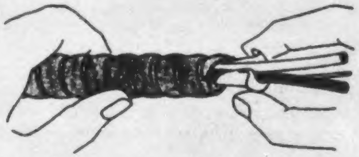


5. Tighten the bolts so connector is secured to cable. Insert into box, install locknut.

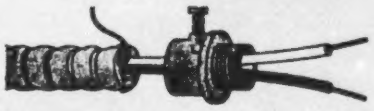
Installing BX cable



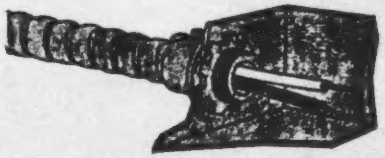
1. Use a hacksaw to cut off about 6 in. of the armor. Be careful not to cut into the wires.



2. Remove 1 in. of insulation from each of the two wires; insert insulating fiber bushing.



3. Install special BX cable connector. Make sure cable fits snugly in it; tighten screw.



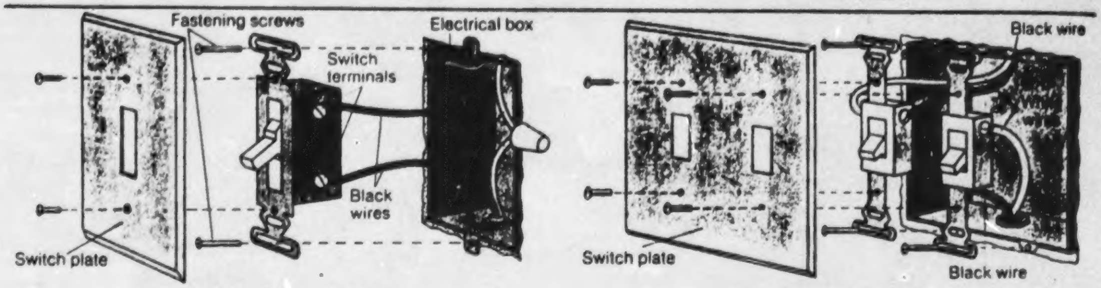
4. Push cable into junction or switch box and install locknut. Allow 6 in. for connection.

SWITCHES AND OUTLETS

Installing a Switch

Switches are always in the hot (black wire) side of the circuit, never in the neutral (white wire) side. So they connect to black wires only, except in switch loops, below, or multiwire switching.

To remove old switches, you must first isolate the circuit that controls the switch. Then remove the switch plate and the screws holding the switch in the switch obx. Tug the switch out of the box so that the wires are accessible. Release the wires from their respective terminals and replace them in the same position on the new switch. Tighten all connections and tuck the wires and the switch back into the box. Fasten the screws and replace the switch plate.



Switch in supply cable

Switch loops to separate fixtures

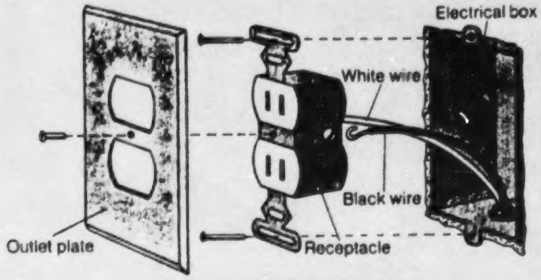
Installing an Outlet

If an electrical outlet is faulty, it will short circuit and blow a fuse (or trip a circuit breaker) whenever an appliance or lamp is plugged into it. To test whether or not an outlet is defective, plug in a lamp you know is working. If the lamp doesn't go on, and the circuit is all right, then the outlet is faulty.

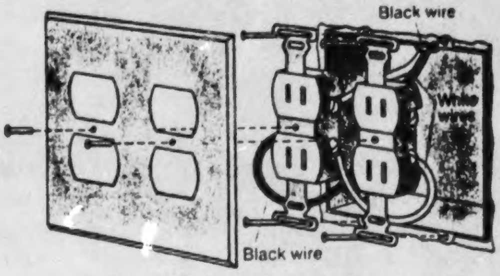
To remove a damaged outlet, turn off the power to the affected circuit. Remove the outlet plate, remove the two screws holding the receptacle, and pull the unit out of the box. Remove the wires from their respective terminals and replace them in the same arrangement on the new receptable. Many new receptacles are the 3-wire grounded type, in which case you can either ignore the ground terminal, or join a short length of wire from the ground terminal directly to the outlet box; follow local code.

Multiple switches and outlets: Usually you would only have to replace one switch or outlet from a faulty multiple hookup. These multiple units should be tested in the same way as the single units.

Position of terminals of multiple switches or outlets may vary slightly on some brands. The important thing is to place all the wires removed from the old switch or outlet on the same screw terminals of the new unit.

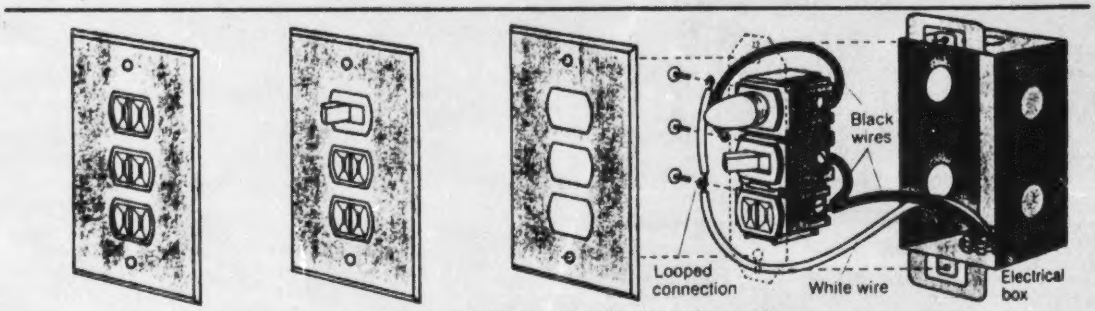


Double electrical outlet



Quadruple electrical outlet: Note positioning of wires

Combination units: Combinations switch/receptacle units are wired similarly to the single and double switches and outlets. Each switch outlet or pilot light requires one common wire obtained by using jumpers to connect all three terminals.



Combination switch and outlet units are interchangeable

Grounding wires are not shown in these pictures.

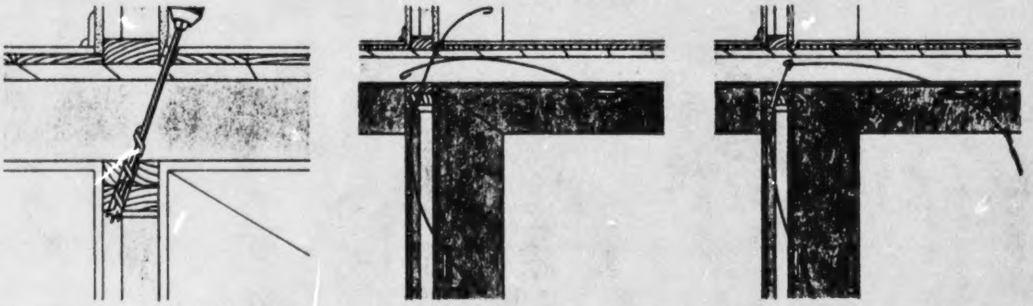
WIRING NEW CIRCUITS

Wiring in new construction is seldom a problem since all studs and ceiling joists are exposed and accessible. Running wires in an existing structure, however, poses the problem of working inside walls. In the case of plaster walls or ceilings, channels must be gouged out for the wires and later replastered. In such instances, surface wiring is easier.

For drywall construction, it is necessary to wire through the spaces between walls and ceilings. The method of doing this is known as "fishing". This is done with fish tape, a springy length of wire that is hooked at one end. It is fed through pre-drilled access holes in ceilings, floors, or walls. The electrical cable is attached to the hook, then pulled through the construction.

Wherever possible, plan to run wires across an attic floor or across the open ceiling of a basement. This will minimize the amount of fishing.

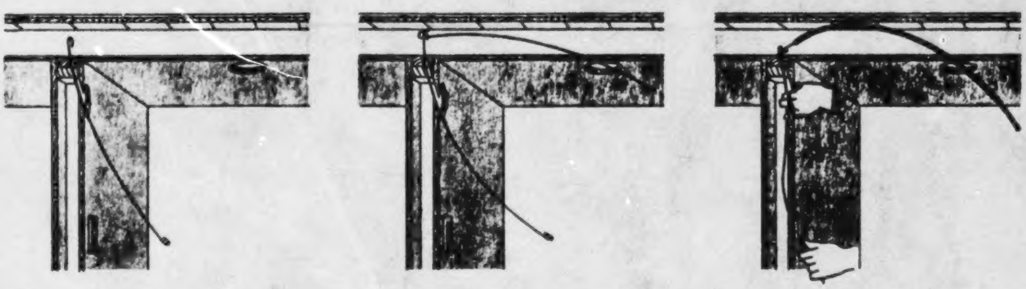
Fishing a wire



If there is a room or attic above, remove baseboard and drill diagonally through supporting beams into wall cavity. Use a brace and 18-in. bit.

Feed a 12-ft. fish tape down from upper room and out the electrical box hole in the wall. Feed a second tape through ceiling hole. Hook the tapes.

Withdraw both tapes through ceiling hole. Bind wire cable around hook, making sure no part of the binding is larger than the bored hole.

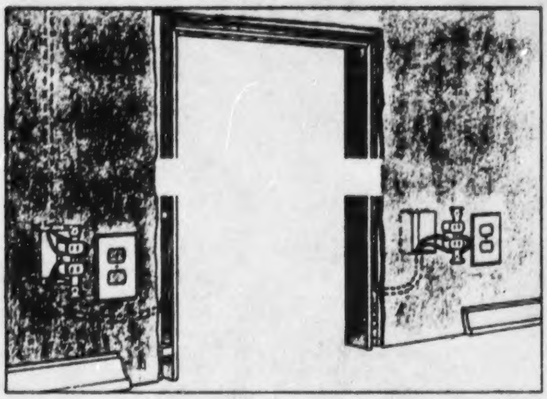


If there is no access above, cut large hole in wall 5 in. from ceiling. Bore diagonally up through support beams into ceiling cavity. Insert fish tape.

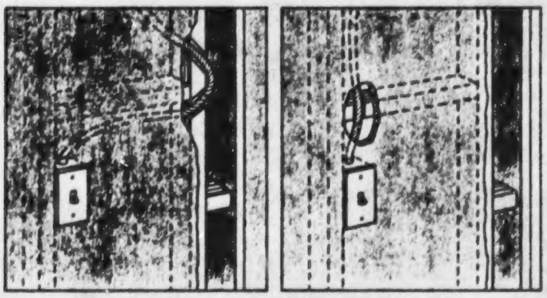
Insert second fish tape through ceiling hole. Fish until tapes interlock. Withdraw tapes through ceiling hole until hook of wall tape can be grasped.

Attach cable to tape hook, then withdraw tape and cable by pulling down through large hole in the wall. Feed free end of tape out box holes.

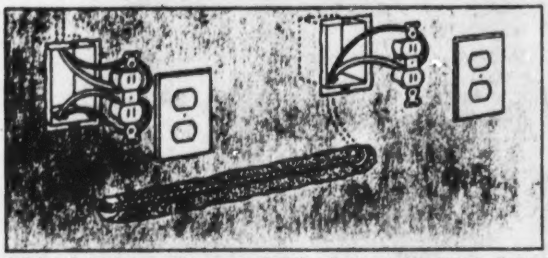
How to Run a Wire



Wiring around door frame: Remove baseboard and door trim. Notch wall and spacers between frame and jamb. Use an 18-in. bit in a brace to drill through headers and uprights.

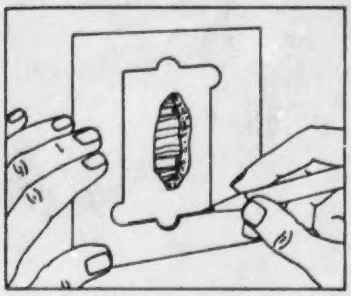


Wiring around door-frame headers: Notch upright twice and wire through both notches. Or make hole in wall, notch header, pass wiring through notch in header. Replaster hole (p. 92).

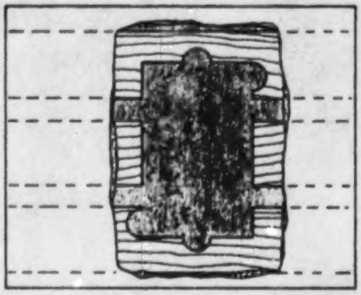


Wiring from one outlet to another in plaster walls: Notch plaster so the wire can run in a channel inside the wall. Notch hole for box. Connect wires and replaster.

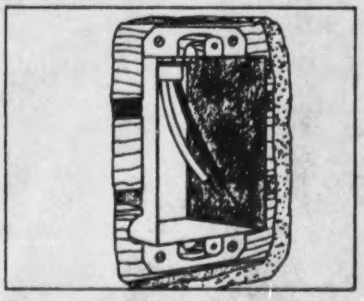
Ideal positioning for switch boxes is about 4 feet from the floor; for outlet boxes, roughly 12 to 18 inches off the floor. Outlets for wall-mounted light fixtures should be 60 to 70 inches above the floor. Be sure to mount switches on the opening side of a door rather than on the hinged side. Always use 2 1/2 inch deep electrical boxes rather than the shallow ones, unless some structural problem will not permit the deeper box. With lath and plaster construction, you can locate an electrical box almost anywhere along the wall, since the wooden lathwork is strong enough to hold the box securely.



Locate stud. Cut an opening in the plaster 5 in. out from stud, large enough to expose laths. Use template at right to outline hole to be made in the wall.



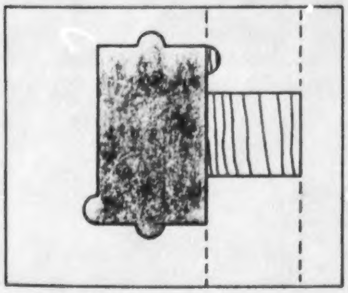
Remove plaster. Drill saw holes. Hold your hand against wall to prevent cracks. Cut away center lath completely. Cut sections from laths above and below.



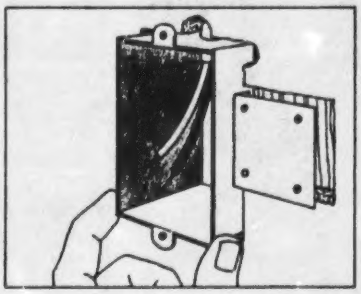
Punch knockout disks from box. Pull wiring through hole. Attach connector. Install locknut. Push box into hole. Anchor box to lath with wood screws.

Drywall Installations

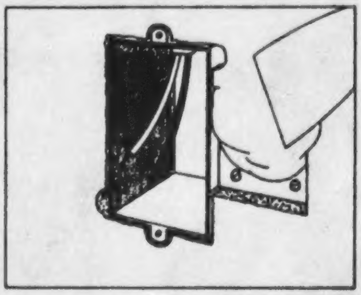
In drywall or wood paneling, boxes can be mounted between studs by means of special clamping devices that grip the inside of the hollow wall. The strongest point in this type of construction, however, is at the studs. You can get boxes equipped with brackets that can be nailed or screwed directly to the face of the studwork. To fit boxes directly onto the studs, you must first locate the stud, then chip a notch out of the drywall large enough to accept the fastening bracket. Connect the wires to the box before placing it in the hole. When installation is complete, patch the hole.



Locate stud. Notch drywall to expose stud. Outline area next to stud with template. Drill saw holes. Hold hand against wall to prevent cracks. Saw out section.



Punch knockout disks from box. Pull wiring through hole. Attach connectors. Install locknut. Line up bracket with stud and push box into hole.



Anchor box bracket to stud with screws. Fill area around box and bracket with either plaster or spackle so that it is flush with the wall surface.

INSTALLING ELECTRICAL BOXES

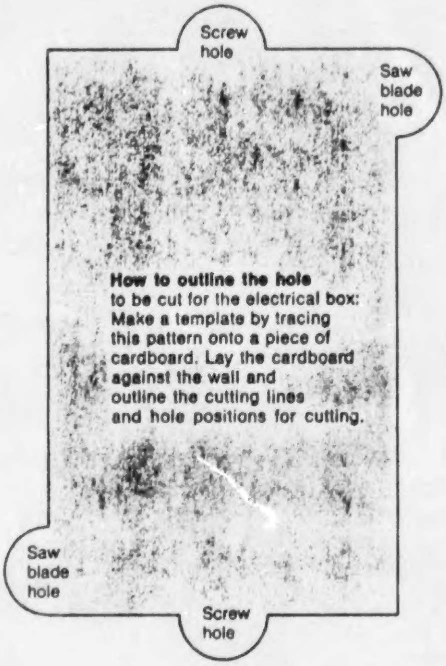
Locating Studs

There are several methods for locating studs. One of the following should work for you:

1. Tap the wall lightly at points above the nails in the baseboard. A hollow sound means there is no stud. A solid sound indicates the presence of a stud. To be sure that you have found the stud, use a small drill (1/8 inch) to bore holes in the wall slightly above the baseboard. Drill several holes side by side until you bore into the stud.

2. Baseboard removal: With the baseboard off, check to see where two panels of drywall meet. This point will indicate the center of a stud. This method also works with paneled walls.

3. Measuring from the corner: Studs are generally located either 16 to 24 inches apart. Which it is depends on local building codes. Try measuring out from the corner of a room to find the approximate location of a stud, then use the drilling technique described above to find the exact stud location.



How to outline the hole to be cut for the electrical box: Make a template by tracing this pattern onto a piece of cardboard. Lay the cardboard against the wall and outline the cutting lines and hole positions for cutting.

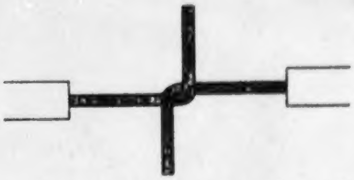
Electrical box template

WIRING SWITCHES, OUTLETS, AND FIXTURES

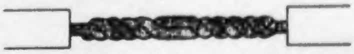
How a switch, outlet, or fixture is wired depends upon its location in relation to the wires that lead from the main service entrance. The diagrams on the following pages show a variety of common switch, outlet, and fixture wiring installations. To use these, find the diagram that most closely resembles your wiring arrangement. Then follow the pattern of joining white wires to white wires and black to black.

The white wires are always neutral, the black ones always hot; however, in certain switch installations both black and white wires are hot. In such cases, you should dab black paint on the white wires at the switch and fixture to indicate a hot wire. DRAWINGS ARE DIAGRAMMATIC, WITHOUT GROUNDING WIRES.

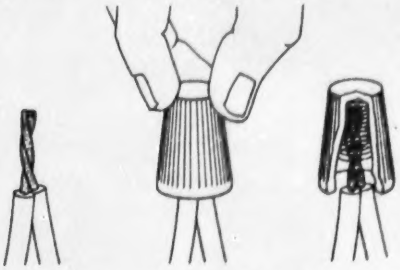
Two-wire joining methods



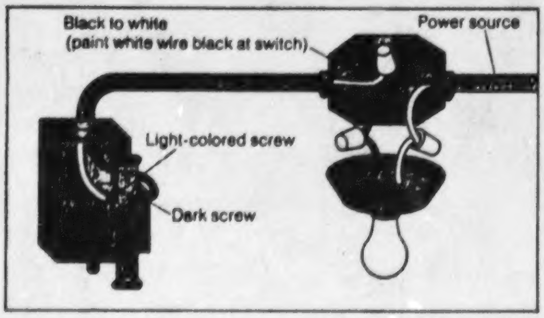
1. Remove 3 in. of insulation from each wire. Cross and twist wires together 1 in. from the insulation.



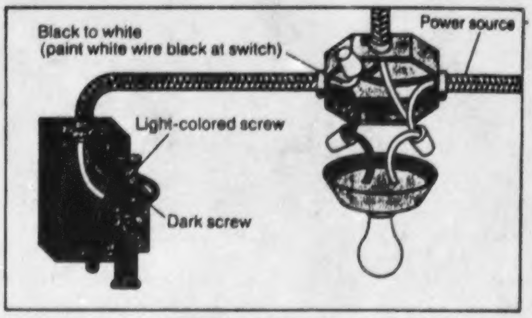
Make six to eight turns in twisted wires with fingers and pliers. Solder wires together. Tape after soldering.



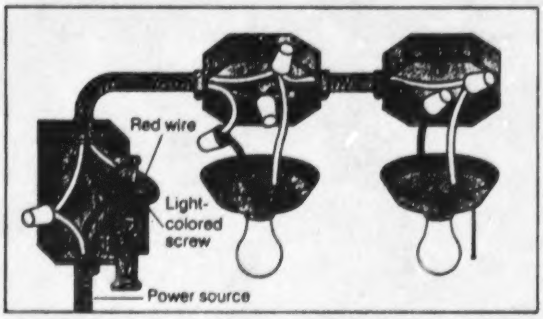
2. Twist ends of wires together as shown. Screw wire nuts on ends to form connections without use of solder.


Black to white
(paint white wire black at switch)
Power source
Light-colored screw
Dark screw

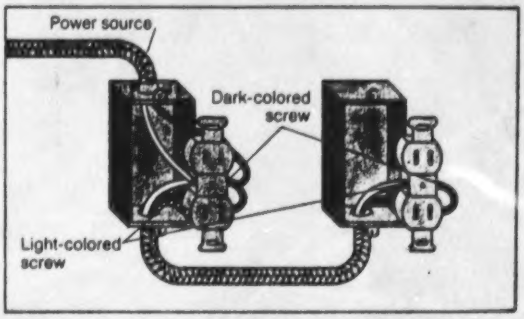
Wall switch to control ceiling fixture at the end of its run: Note that black feed wire is connected to white wire from the switch. Paint white wires at fixture and switch black.


Black to white
(paint white wire black at switch)
Power source
Light-colored screw
Dark screw

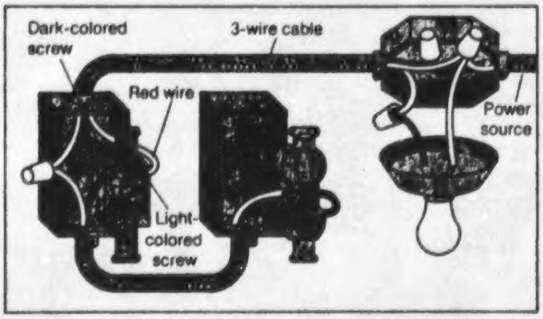
Wall switch to control ceiling fixture in the middle of run: This wiring hookup is similar to wiring at left. Paint white wires at switch and fixture black to indicate they are hot.


Red wire
Light-colored screw
Power source

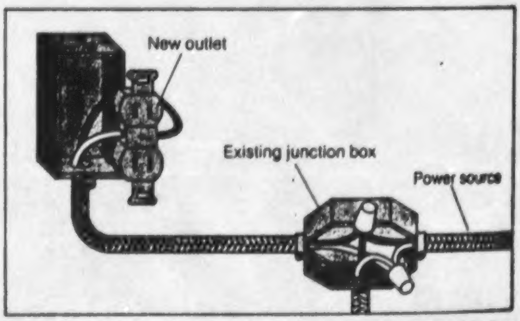
Two fixtures on the same line controlled by different switches: Fixture on left is controlled by switch to the left. Fixture on right is controlled by pull chain on fixture.


Power source
Dark-colored screw
Light-colored screw

Adding a supplementary outlet to an existing outlet: Connect feed wire to top terminals on existing outlet (left). New outlet is connected to lower terminals.

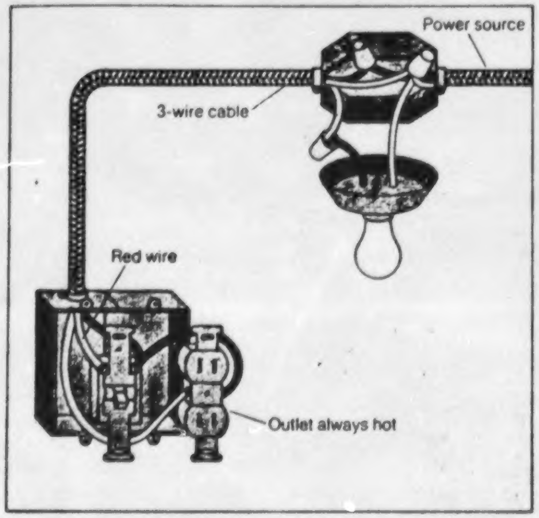

Dark-colored screw
3-wire cable
Red wire
Power source
Light-colored screw

Adding a new switch and outlet to an existing ceiling fixture: Fixture is controlled by wall switch. Operation of new outlet is unaffected by operation of wall switch.

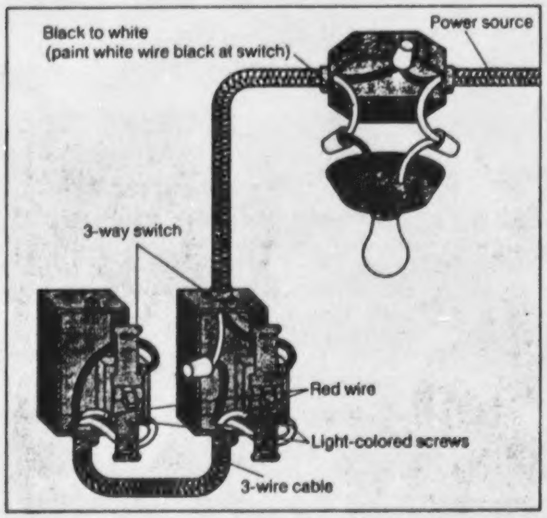

New outlet
Existing junction box
Power source

Adding a new outlet or fixture to an existing junction box: Same wiring arrangement as for outlet could be used to connect a new ceiling fixture instead of an outlet.

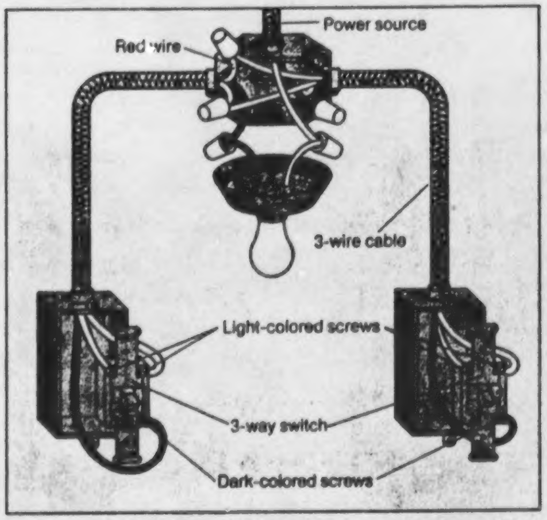
Wiring 2-, 3-, and 4-way switches


Power source
3-wire cable
Red wire
Outlet always hot

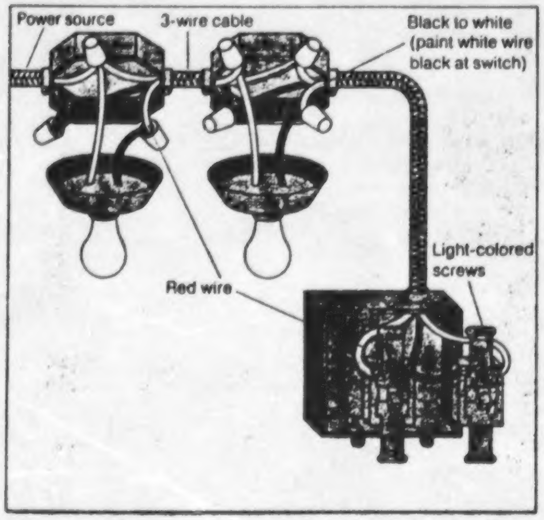
Adding switch and outlet in the same box to ceiling fixture: Existing ceiling fixture is controlled by new switch. Operation of new outlet is unaffected by new switch.


Black to white
(paint white wire black at switch)
Power source
3-way switch
Red wire
Light-colored screws
3-wire cable

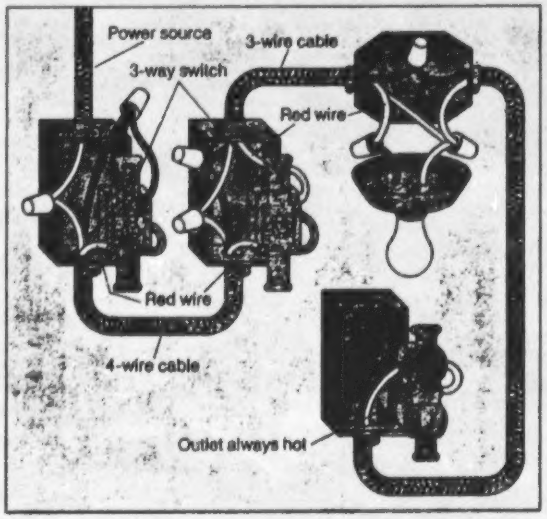
Same ceiling fixture controlled by two different switches: Three-wire cable must be used between switches. Either switch, each located at a different spot, can control fixture.


Power source
Red wire
3-wire cable
Light-colored screws
3-way switch
Dark-colored screws

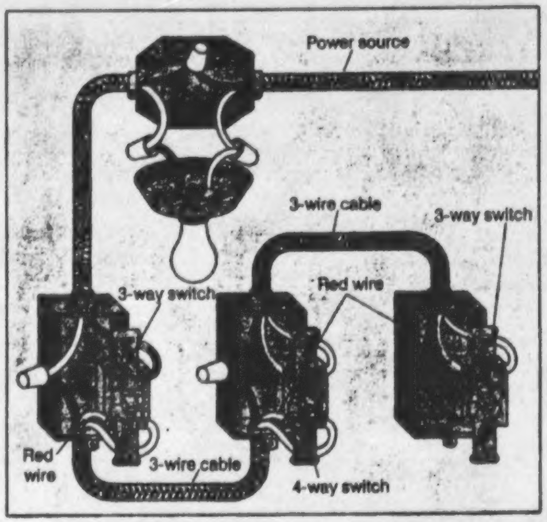
Ceiling fixture between two switches, controlled by either: Three-wire cable connects each switch to the fixture. Feed wire to fixture is a 2-wire cable.


Power source
3-wire cable
Black to white
(paint white wire
black at switch)
Light-colored
screws
Red wire

Two separate fixtures controlled by two switches: Left fixture controlled by left switch. Feed wire is 2-wire cable. Fixture and switch connections are 3-wire.


Power source
3-wire cable
3-way switch
Red wire
Red wire
4-wire cable
Outlet always hot

Fixture controlled by separate switches; outlet always hot: Feed wire and outlet connections are 2-wire cable; connections between switches and outlet, 4-wire cable or two 2-wire cables.


Power source
3-wire cable
3-way switch
3-way switch
Red wire
Red
wire
3-wire cable
4-way switch

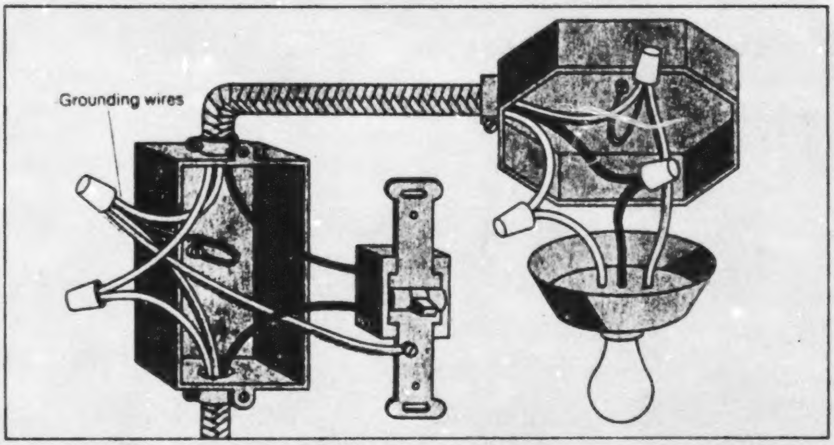
Ceiling fixture controlled from three separate locations: Two 3-way switches and one 4-way switch are required. Each extra control point requires an additional 4-way switch.

IV-S-443

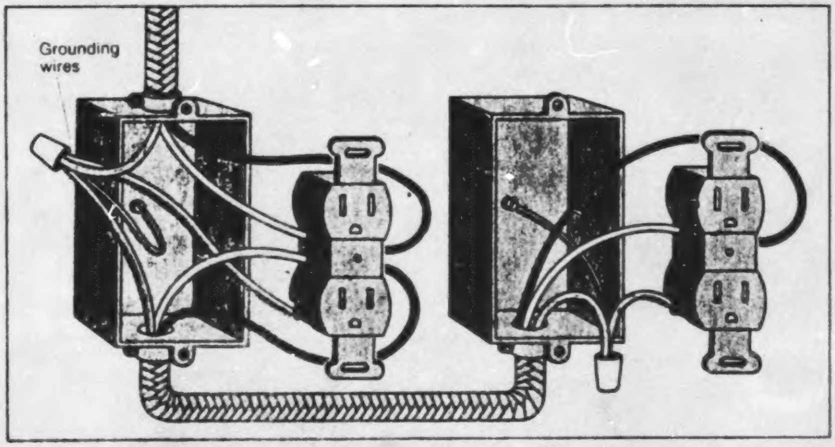
WIRING CODE

New Grounding Requirements

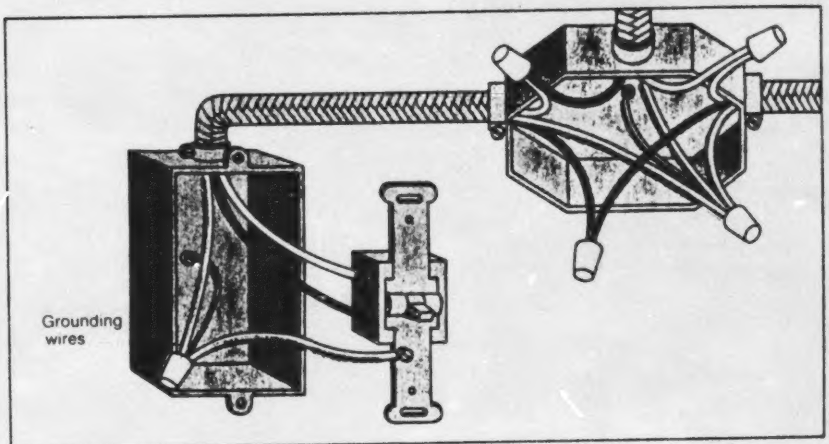
The National Electrical Code now requires that new residential outlets be grounded by a grounding wire, or "jumper", connected between a grounded outlet box and the grounding terminal of the receptacle. A grounding screw is provided for this purpose in many new boxes; if it is lacking, buy a special grounding connector. The reason for the jumper is to provide a secure grounding path. Grounding may be established by contact between the outlet box and the receptacle's metal yoke where this type of contact is adequate, as on surface-type boxes. Flush-type outlet boxes, however, are frequently installed too deeply in the wall to permit sound metal-to-metal contact between yoke and box. Grounding, in these cases, depends upon the uncertain electrical path provided by the mounting screws; so the jumper is used. If the yoke is specially designed to provide a reliable grounding circuit between box and receptable, it will suffice. Check you local code. Not all switches have grounding terminals, which are often used with nonmetallic boxes.



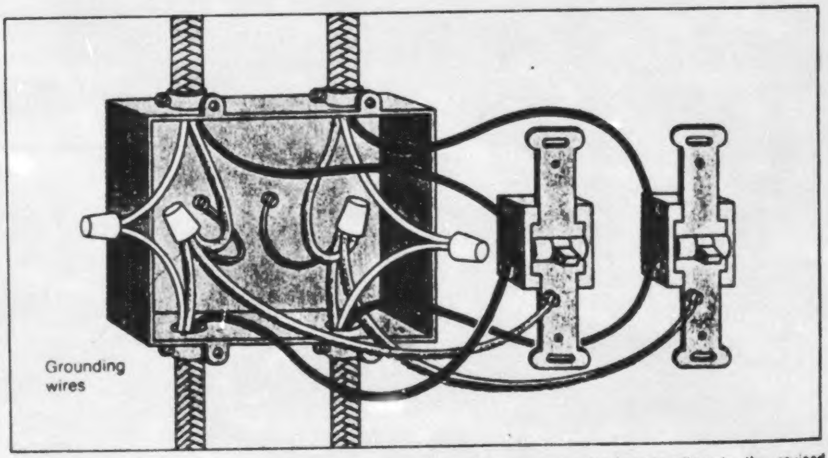
Wiring hookup for a light controlled by a switch, using the new grounding system. All new wiring must have an extra wire as a ground; with Romex, use the bare middle wire.



Extending power to a new outlet. Both outlets have a self-grounding strap and binding post that is connected by means of the jumper wire to the grounding post in each box.



Switch wired through junction box controls light at far end of cable. This type of wiring is called a switch loop. White wire leads to switch; black wire leads from switch to fixture.



Two switches independently controlling two ceiling fixtures and wired according to the revised code. Grounding terminal is lacking on many switches but must be used if required by local code.

Outdoor Installation Requirements

Outdoor receptacles must be the weatherproof type. They usually have a spring-loaded cover to seal them when they are not in use. The juncture between the cover plate and the wall surface must also be made water-tight with a caulking compound.

Surface-mounted receptacles also have a weather-proof outlet box mounted on the outside face of the wall rather than flush with the wall. Wiring for either type is led to the box through a length of threaded conduit. All wiring to outside outlets must now be protected by a ground fault interrupter (GFI). Grounding and wiring connections are the same as for an indoor receptacle.

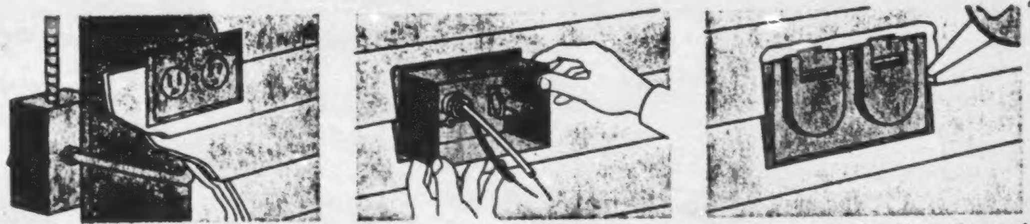
Only fixtures and wire approved for outdoor use should be used. If the appliance be will be exposed to the weather, it should be a weatherproof type.

One way to make the wiring passage through the house wall is with conduit (the rigid, threaded type) screwed to the back of the box. If the conduit leads to a grounded junction box inside the house, and is properly connected, it serves to ground the outside fixture. If the conduit merely passes through the wall and serves only as a channel for the cable, the cable must be grounded.

Any tools or appliances that are plugged into an outdoor outlet should be of the grounding or double-insulated type; make certain that their cords are not frayed. Extension cords should be of sufficient capacity that they will convey current to the tool without a drop in the voltage.

CAUTION: Before doing any wiring, always make certain that you have turned off the current and that you will be complying with your local electrical code.

Outdoor outlet

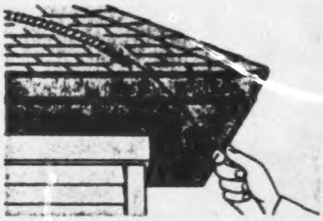


Wire an outdoor receptacle to the nearest junction box in the house. Switch can be used to control outlet.

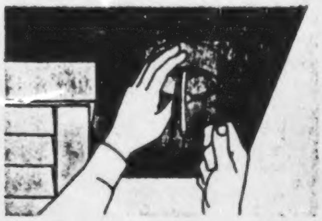
Cut hole in wall of house to exact size of outlet box. Secure cable; leave 4 in. of wire for connections.

Install the receptacle with weatherproof faceplate. Caulk opening around box to prevent water getting into outlet.

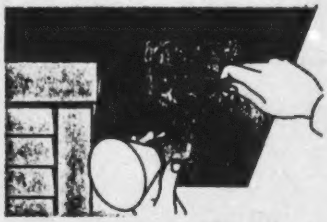
Eave light



Connect cable to power inside house and pass it through a 1-in. hole drilled in the soffit. Work with current off.

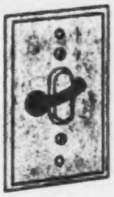


Secure the cable end to special outdoor box with locknut. Allow 4 in. of wire for connections.

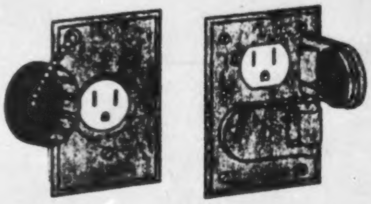


Connect white wire to white wire and black to black. Secure socket assembly with the bolts provided.

Accessories

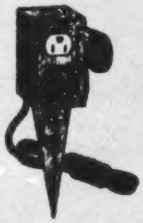


Switch for outdoor use is especially designed to be weatherproof.



Weatherproof outlets have screw-on caps or spring-loaded lids to protect the openings from the elements.

Special outdoor boxes must be used with outdoor switches, outlets.



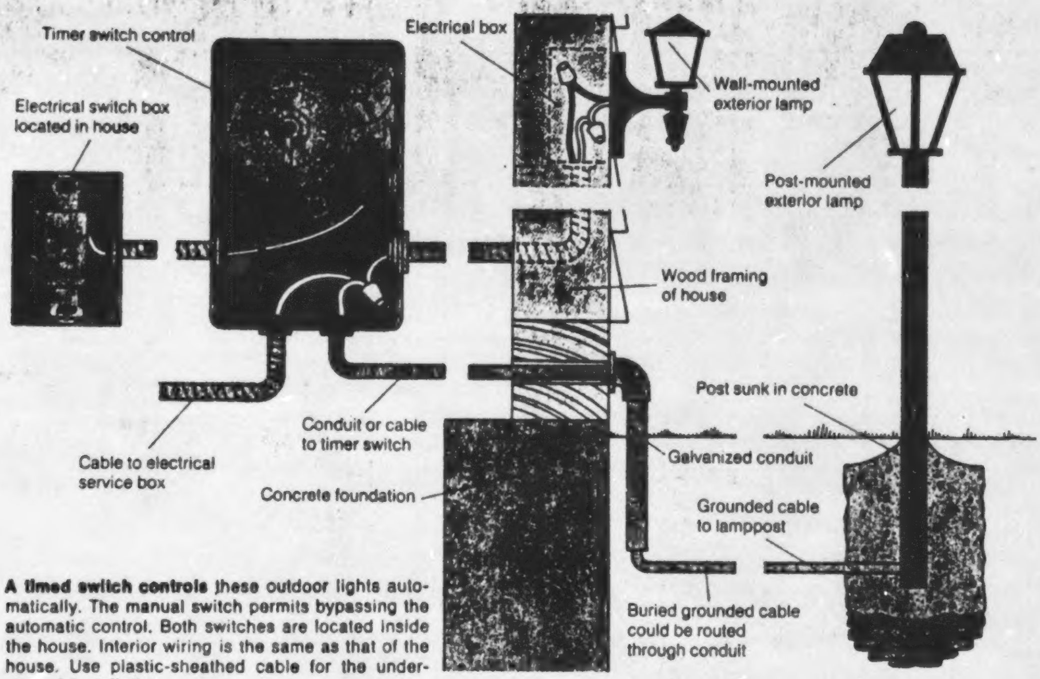
Portable outdoor outlet is grounded by third wire in the cord.

Example Outdoor Installations

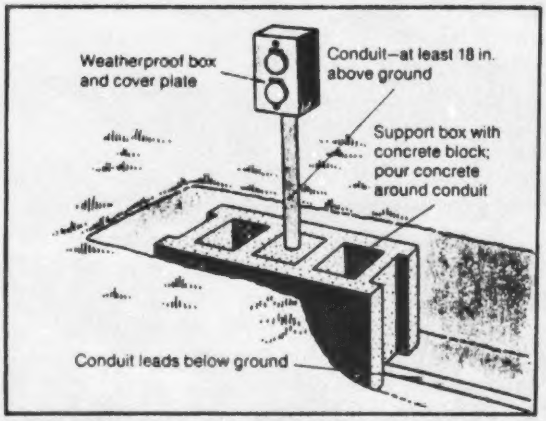
Cut or drill holes in the side of the house close to the fuse or circuit breaker box. If your house is wood, make certain that the holes are located between studs. Holes in concrete or stone can be made with a star drill. Areas around the holes and each end of conduit should be plugged with caulking compound after the wiring or cable is installed.

To prevent damage to the lawn when you dig a trench between house and fixtures, cut sod into blocks with a long-handled spade and lay them aside on burlap. Locate electrical boxes and fixtures at least 18 inches above ground and anchor them in concrete. Bury cable at least 18 inches below the ground to protect it from gardening tools. You can bury cable as little as 6 inches below the ground if it is covered to protect it against damage or, safer still, routed through galvanized conduit.

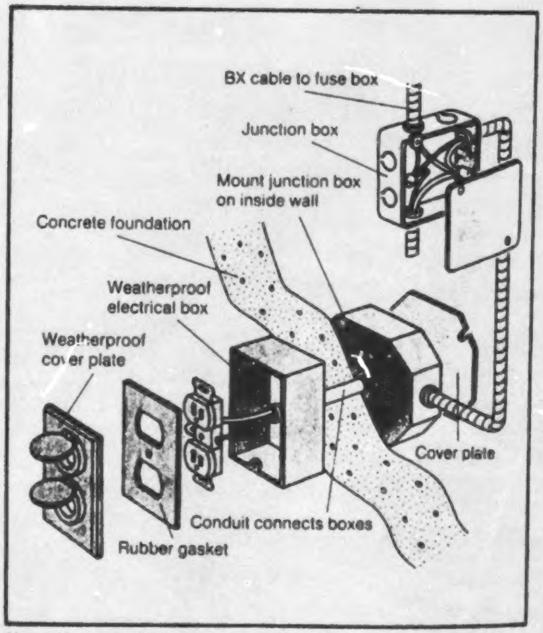
Make sure all outdoor wiring is complete and all terminals connected before connecting the wiring to the fuse or circuit breaker box.


Timer switch control
Electrical box
Electrical switch box located in house
Wall-mounted exterior lamp
Post-mounted exterior lamp
Wood framing of house
Post sunk in concrete
Conduit or cable to timer switch
Cable to electrical service box
Galvanized conduit
Concrete foundation
Grounded cable to lamppost
Buried grounded cable could be routed through conduit

A timed switch controls these outdoor lights automatically. The manual switch permits bypassing the automatic control. Both switches are located inside the house. Interior wiring is the same as that of the house. Use plastic-sheathed cable for the underground installation.


Weatherproof box and cover plate
Conduit—at least 18 in. above ground
Support box with concrete block; pour concrete around conduit
Conduit leads below ground

Freestanding electrical boxes should be at least 18 in. above ground level. Set them atop a length of galvanized conduit that is embedded in a concrete support block.


BX cable to fuse box
Junction box
Mount junction box on inside wall
Concrete foundation
Weatherproof electrical box
Weatherproof cover plate
Cover plate
Conduit connects boxes
Rubber gasket

Use this electrical box arrangement when running wires from inside the house to a weatherproof box mounted on the exterior wall. Run connecting cable through conduit.

SOLDERING TECHNIQUES

When wiring electrical circuits, it is imperative that all solder joints be of good quality if long lasting, trouble-free joints are to be expected. Always use a good quality rosin core electrical solder of 60/40 or 50/50 tin to lead content.

The first rule when soldering is "cleanliness". This means that both the surfaces to be joined must be clean and the soldering iron or gun tip must be clean. Whenever a new tip is installed in a soldering iron or gun, it must be tinned. To do this, clean the tip with either a fine tooth file or abrasive cloth until a bright clean surface is showing. Then with the tip hot enough to melt the solder, flow a small quantity of solder onto the tip. The solder should be applied around the entire tip until it has a clean, wet, silver look. Wipe the excess off with a wet sponge or cloth. Whenever solder tends to ball up or not stick to the tip, it is time for cleaning and re-tinning.

Cleanliness also is required of the joints to be soldered. If a wire is being soldered to a lug, both must have clean bright surfaces. If either is dull, it can be cleaned with a few wipes from a piece of abrasive cloth.

Pre-tinning of the wire prior to making a solder joint will result in a clean looking joint with good solder adhesion. This is especially true of joints made with stranded wire. To pre-tin a wire, heat it with the soldering tip and apply a small amount of solder to the side opposite the tip. The solder will melt and completely cover the wire with a thin film. Don't over tin; only a thin film of solder is necessary.

When forming the wire joint prior to soldering, either of two approaches may be used. As shown in figure 1-66, the wire may be bent 180° around the lug or joining wire, or bent completely around. The advantage of a bend only 180° around is its ease of disassembly. It is, however, somewhat harder to make because of its likelihood of moving around and away from the joining surface as it is being soldered. The 360° wraparound joint is mechanically a better joint, but much harder to disassemble.

When making the solder joint, first apply heat at the connection point. Bring the solder in contact with the heated surfaces opposite to those heated by the soldering tip. This method assures that the surfaces to be joined are hot enough to flow the solder. If the surfaces have been properly cleaned, you will get a smooth flow of solder over the joint with the edges of the solder blending smoothly to both joined materials. Don't apply any more solder than is necessary to make a good smooth looking joint. The surface should have a bright appearance. A dull chalky appearance or crystalline and grainy look indicates a cold solder joint. Such a joint may not make good electrical contact and is a joint for potential electrical circuit failure. Such joints are often caused by slight movement of the joint while the solder is hardening. If this is the case, reheat the joint and let it cool, being careful not to let any part of the joint move.

Occasionally the solder will ball up on the joint. This can be caused either by the urfaces not being properly cleaned or by application of too much or not enough heat to the joint. If this occurs, disassemble the joint, reclean the surface, and again flow solder onto the joint, being careful to apply only enough heat to freely flow the solder into the joint.

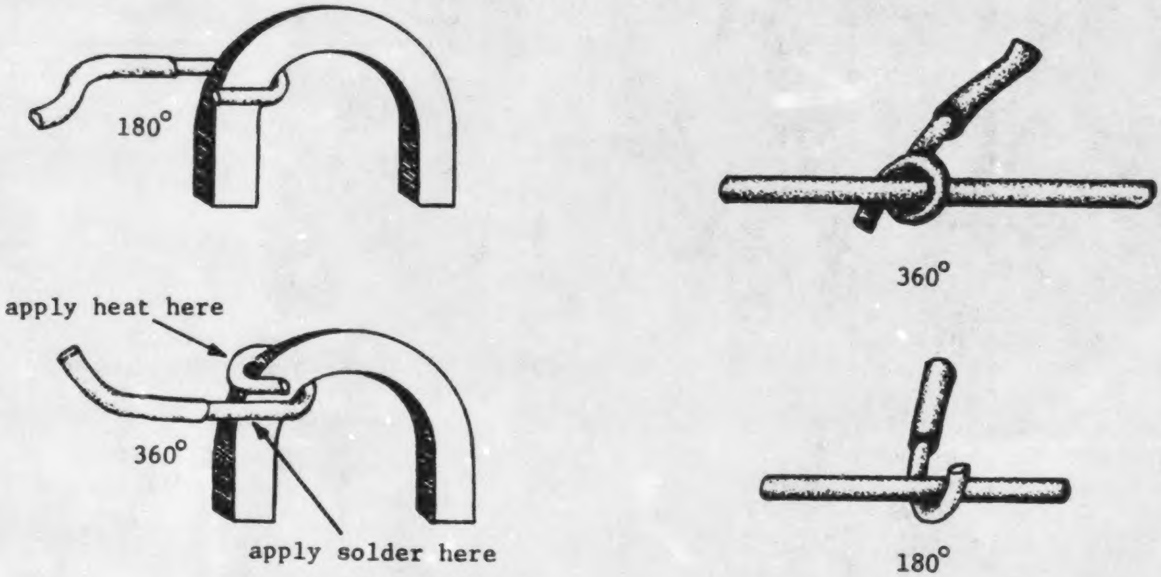


FIGURE 1-66
WIRE TERMINATIONS PRIOR TO SOLDERING

When soldering components to PRINTED CIRCUIT (PC) BOARDS the soldering tip should be brought in contact with both the PC trace and the wire to be soldered. A small amount of solder is then applied to the wire side opposite the soldering tip. Apply only enough solder to make a joint.

GLOSSARY

alternating current (AC) — a current whose flow changes from one direction to another and back.

ammeter — an instrument used for measuring the amount of current (in amperes) flowing in a circuit.

ampere — the movement of one coulomb per second past a point.

anode — the terminal of a diode from which electrons leave to enter an external circuit.

apparent power — the value of power in ac circuits obtained by multiplying the magnitude of voltage and current.

base — the region between the emitter and collector of a transistor into which minority carriers are injected. Usually serving as the input or controlling element of the transistor's operation.

battery — a dc voltage source made up of two or more cells connected in series to supply voltage or in parallel to supply current, or both.

bridge supply — a full-wave supply that uses four diodes as its rectifier; does not require a center tap transformer.

capacitance — the property that exists whenever two conductors are separated by a dielectric, permitting the storage of electrical energy. Farad is the unit of measurement.

capacitive reactance — the opposition to the flow of current exhibited by a capacitor.

capacitor — a device capable of storing a charge within an electrostatic field between its conducting plates.

cathode — the terminal of a diode to which electrons enter from an external circuit.

cell — a single unit device that converts chemical energy into electrical energy.

circuit — an arrangement of one or more complete paths for current flow from one terminal to the other.

closed circuit — a complete circuit that allows current to flow.

close-wound coil — a single layer wound coil whose wires are wound closely together.

coil — a number of turns of wire wrapped around a core that provides inductance into an electric circuit. Also called an inductor.

collector — the electrode in a transistor through which primary flow of charge carriers leaves the base.

constant DC source — a source for direct current such as a cell or battery.

conventional current flow theory — the direction that conventional current flows in a circuit, being equal in magnitude and opposite in direction to the electron flow theory.

coulomb — 6.25 x 10^{18} electrons.

current — the flow of electrons through a material.

current transformation — the change in value of current that flows through a transformer primary and secondary; is inversely proportional to the turns ratio.

dielectric — the insulating material between the two plates of a capacitor.

dielectric constant — the ratio of the capacitance of a capacitor filled with a given dielectric to that of the same capacitor having only air as dielectric.

differential temperature controller (DTC) — a device that switches an output state when a preset temperature differential between two temperature sensors is reached.

digital multimeter (DMM) — a meter with digital readout of measured values of voltage, current, and resistance.

diode — a single junction solid state device that allows current to flow with ease in one direction only.

direct current (DC) — a current whose flow is always in the same direction.

dopants — materials added to silicon to give it certain electrical current conduction characteristics.

double pole, double throw (DPDT) — a switching device having two armature (common) terminals and two possible switching positions.

double pole, single throw (DPST) — a switching device having two armature terminals which may be thrown in one direction to close or open two circuits.

effective working voltage — equivalent to RMS voltage.

electrolytic capacitors — a type of capacitor that is polarity dependent, i.e., a voltage can be placed across its plates in only a designated polarity without damaging it.

electro-motive force (EMF) — a measure of the electrical pressure or potential difference that causes current to flow.

electron flow theory — the direction that electrons flow in a circuit, i.e., from the − to the + side of the source.

emitter — a transistor region from which charge carriers that are minority carriers in the base are injected into the base.

farad — the standard unit of capacitance. A capacitor has a capacitance of one farad when a voltage change of one volt per second across its plates produces a displacement current flow of one ampere.

full-wave power supply — a power supply whose rectifier operates on both the positive and negative alternation of the ac sinewave.

ground — the voltage reference point in a circuit which may be connected to earth or to some conducting body serving in place of earth.

half-wave power supply — a power supply whose rectifier operates on only the positive or negative alternation of the ac sinewave.

heat sink — a device that absorbs and draws off heat from a hot object.

henry — the standard unit of inductance. A coil has an inductance of one henry when it produces one volt when the current through it is changing at the rate of one ampere per second.

hertz — the unit of frequency equal to one cycle per second. Abbreviated Hz.

impedance — the opposition to the flow to alternating electrical current.

inductance — the property of a circuit or circuit element which opposes any change in the existing current flow. Abbreviated L.

inductive kickback — the back (or reverse) voltage developed within an inductor when its magnetic field collapses.

inductive reactance — the opposition to the flow of current exhibited by an inductor.

inductor — a coil of wire wrapped around a core to provide inductance to a circuit.

integrated circuit (IC) — a complete functional circuit made up of many solid state junctions and manufactured on a very small chip of silicon.

intensity — magnitude of current.

kilo — a metric prefix representing 1000 or 10^3. Abbreviated K.

Kirchoff's current law — the sum of the currents flowing to a given point in a circuit is equal to the sum of the currents flowing from that point.

Kirchoff's voltage law — the algebraic sum of all the voltage drops around a circuit equals zero.

latching relay — a relay that requires a signal to switch to each position.

layer-wound coil — a multilayer wound coil whose wires are wound very close together.

load — a device or circuit that receives electrical energy from another device or circuit. Also the power output capability of a machine.

magnetic field — an area where a magnetic force exists.

mega — a metric prefix representing one million or 10^6. Abbreviated M.

micro — a metric prefix representing one millionth or 10^{-6}. Abbreviated μ.

milli — a metric prefix representing one thousandth or 10^{-3}. Abbreviated m.

node — a junction. The terminal common to two or more branches in a circuit.

normally closed contact (N.C.) — this set of contacts is closed when the device is de-energized.

normally open contact (N.O.) — this set of contacts is open when the device is de-energized.

NPN transistor — a two junction solid state device with a thin piece of P-type material sandwiched between two pieces of N-type material.

ohm — the unit of resistance and impedance. One ohm is the value of resistance through which a potential difference of one volt will maintain a current of one ampere.

Ohm's law — the current in a circuit is inversely proportional to the resistance of the circuit and is directly proportional to the total voltage in the circuit. Three common equations for the law are: $E = IR$, $I = E/R$, $R = E/I$.

open circuit — a circuit that has a brake in it so that current cannot flow.

parallel circuit — a circuit whose elements are connected in parallel.

parallel-series circuit — two or more parallel circuits connected together in series.

peak inverse voltage (PIV) — the maximum reverse voltage to which a diode may safely be subjected to.

permeability — a figure which expresses the ease by which a material passes a magnetic field.

pico — a metric prefix representing one million millionth or 10^{-12}. Abbreviated p.

PNP transistor — a two junction solid state device with a thin piece of N-type material sandwiched between two pieces of P-type material.

power — the rate at which heat is generated or work is done.

power dissipated — power in the form of heat, which escapes from components due to air convection moving around the component.

power factor — the numerical value of the cosine of the angle between the voltage and current wave forms.

primary winding — the input winding of a transformer that receives signal energy or ac power from a source.

printed circuit (PC) boards — circuit boards of insulating material with conducting traces bonded to the board. The conducting traces are in lieu of conducting wires.

pulsating DC source — a source for pulsating direct current such as a battery charger.

reactance — the opposition to the flow of current by a capacitor or an inductor.

real power — the value of power in ac circuits obtained by multiplying the magnitude of in phase components of voltage and current.

relay — an electro mechanical device capable of using a signal to close or open a set of contacts that can in turn be used as a mechanical switch.

resistance — the opposition to the flow of current that generates heat.

resistor — a device which resists the flow of electric current or provides a voltage drop in a circuit. Abbreviated R.

ripple — the periodic varience in voltage magnitude that rides on top of a dc voltage level. It is an indication of the quality of the filter capacitor in a dc power supply.

root mean squared (RMS) — square root of the average of the sum of the squares of instantaneous values of a voltage or current waveform.

secondary winding — the output winding of a transformer that receives energy from the primary winding.

series circuit — a circuit whose elements are connected in series.

series-parallel circuit — a circuit that contains both series and parallel circuits in combinations.

short circuit — a circuit whose normal current path has been shunted by a relatively low resistance path.

single pole, double throw (SPDT) — a switching device having one armature (common) terminal and two possible switching positions.

solenoid — a coil with a movable iron core used to convert electric energy into mechanical energy. Can also be a multi-layer coil used as an electromagnet having a straight iron core.

solenoid operated valves — valves that are operated by the movement of a solenoid.

space-wound coil — a loosely wound coil whose wires are not touching one another.

terminal — a connection point on a device at which a voltage is to be applied.

transformer — a device which transforms ac voltages from one magnitude to another.

transistor — an active semiconductor device having three or more electrodes. The main electrodes are the emitter, collector and base.

troubleshooting — locating and repairing malfunctions in equipment.

turns ratio — in a transformer, the ratio of the number of turns in the primary to the number of turns in the secondary.

varying DC source — a source for varying direct current such as a photovoltaic cell.

volt — the unit of voltage or potential difference. Equivalent to the force required to produce a current of one ampere through a resistance of one ohm. Abbreviated V.

voltage — a measure of the electrical pressure or potential difference that causes current to flow.

voltage drop — the difference in voltage between two points, due to the loss of electrical pressure as a current flows through an impedance.

voltage frequency — the rate in hertz at which a voltage will change from + to − polarity.

volt-ampere (VA) rating — the maximum rating of a transformer, obtained by multiplying its output voltage by the maximum current it can supply.

volt-ohmmeter (VOM) — an instrument used to measure voltages, resistances, an also sometimes, currents.

volts AC (VAC) — an alternating current voltage magnitude.

volts DC (VDC) — a direct current voltage magnitude.

watt — the unit of power. The power required to do work at the rate of one joule per second. Abbreviated W.

ERIC Clearinghouse for Junior Colleges
8118 Math-Sciences Building
University of California
Los Angeles, California 90024
AUG 5 1983